THE

ENCYCLOPAEDIA OF RADIO AND TELEVISION

A COMPLETE ALPHABETICAL REFERENCE TO ALL ASPECTS OF MODERN RADIO TECHNOLOGY

Second Edition, with Appendix

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THE ENCYCLOPAEDIA OF RADIO AND TELEVISION

HOW TO USE THIS ENCYCLOPAEDIA

THIS ENCYCLOPAEDIA has been produced primarily to provide easy reference to all the major aspects of modern radio and television. It will meet the requirements of students and practising engineers, as well as those of all radio amateurs. The treatment is simple but, at the same time, completely authoritative; accuracy has not been sacrificed on the altar of simplicity.

Entries are arranged in strict alphabetical order, irrespective of hyphenation and whether two or more words comprise a term. Adequate cross-references are given throughout; where it is useful or necessary to refer to other entries for further information, suitable references are printed, for clarity, in small capital letters.

Wherever it has been considered helpful, the text has been illustrated by pictures and diagrams. All illustrations are given Fig. numbers, commencing at 1 for each separate alphabetical section, and are appropriately referred to in the text.

Much thought has been given to the choice of terms included, bearing in mind that some of those employed in the early days of radio were ill-chosen and have since lost their original meaning. In general, definitions are confined to terms accepted or given preference by responsible bodies, and to those in regular use by qualified radio engineers. Certain obsolescent and deprecated terms still in use have been entered, however, but with a cross-reference to their preferred counterparts. For example, under *radio transmitter* the reader is referred to *sender*, under *coil* to *inductor*, under *condenser* to *capacitor*. . . . These accord with recommendations of the British Standards Institution.

NOTE ON THE SECOND EDITION

THE steady advance of electronic engineering inevitably renders a book such as this out-of-date fairly soon after its publication. With the need to reprint the Encyclopaedia, therefore, the opportunity has been taken to introduce references to some of the more important developments in radio since the original text was completed. This new material is given as an Appendix (starting on page 693), to be consulted in conjunction with the main body of text; the additional entries deal mainly with television and frequency-modulation techniques. At the same time, some obsolete material has been removed from the original text.

THE EDITOR.

ABBREVIATIONS

The following common and technical abbreviations have been employed in the compilation of this encyclopaedia:

A.C.	alternating current
A.F.	audio frequency
A.G.C.	automatic gain-control
Ah.	ampere-hour(s)
amp.	ampere(s)
approx.	approximately
B.S.S.	British Standard Specification
B.Th.U.	British Thermal Unit
C.	Centigrade
c.c.	cubic centimetre(s)
cm.	centimetre(s)
cos	cosine
C.R.T.	cathode-ray tube
c/s	cycle(s) per second
C.W.	continuous waves
cwt.	hundredweight
db.	decibel(s)
D.C.	direct current
D.C.C.	double-cotton covered
deg.	degree(s)
D.F.	direction-finding
dia.	diameter
D.S. & enam.	double-silk and enamel
D.S.C.	double-silk covered
e.g.	for example
e.m.f.	electromotive force
etc.	*et cetera*, and the rest
F.	Fahrenheit
F	farad(s)
g.	gramme(s)
G.B.	grid bias
H	henry(s)
h.p.	horse power
H.T.	high tension
I.C.W.	interrupted continuous waves
i.e.	that is
I.F.	intermediate frequency
in.	inch(es)
K.	Kelvin
kc/s	kilocycle(s) per second
kg.	kilogramme(s)
kV	kilovolt(s)
kW	kilowatt(s)
lb.	pound(s)
log	logarithm
L.S.	loudspeaker
L.T.	low tension
m.	metre(s)
mA	milliampere(s)
mA/V	milliampere(s) per volt
M.C.	moving coil
Mc/s.	megacycle(s) per second
M.C.W.	modulated continuous waves
µF	microfarad(s)
min.	minute(s)
mm.	millimetre(s)
µµF	micromicrofarad(s)
m.p.h.	miles per hour
µV/m.	microvolt(s) per metre
mW	milliwatt(s)
MW	megawatt(s)
Ω	ohm(s)
oz.	ounce(s)
p.d.	potential difference
pF	picofarad(s)
Q.P.P.	quiescent push-pull
q.v.	which see
rev.	revolution(s)
R.F.	radio frequency
r.m.s.	root mean square
r.p.m.	revolutions per minute
R.T.	radio telegraphy
S.C.C.	single-cotton covered
sec.	second(s)
S.G.	screen grid
sin	sine
sp.gr.	specific gravity
sq.	square
S.S.C.	single-silk covered
S.W.G.	Standard Wire Gauge
sync.	synchronizing
tan	tangent
temp.	temperature
T.R.F.	tuned radio-frequency
V	volt(s)
VA	volt-ampere(s)
V.F.	voice frequency
V.H.F.	very high frequency
W	watt(s)
Wh.	watt-hour(s)
yd.	yard(s)

A

A. Abbreviation for AMPERE(S).

A-AMPLIFIER. Synonym for MICROPHONE AMPLIFIER.

A-BATTERY. American term for LOW-TENSION BATTERY.

ABNORMALLY POLARIZED WAVE. Radio-wave polarized in a plane which is neither horizontal nor vertical. In practice, such waves are usually found to have circular or elliptical polarization. See CIRCULAR POLARIZATION, ELLIPTICALLY POLARIZED WAVE, POLARIZATION.

ABSOLUTE UNITS. System of units which can be defined in relation to, and is derived from, the basic units of time, length and mass.

ABSORBER CIRCUIT. In a sender, a circuit, usually employing a valve, which absorbs the power from the sender when a break occurs in a certain part of the circuit. Without an absorber circuit, a break in an oscillatory circuit could cause a surge across the points at which the break occurs, producing an arc and causing damage to the apparatus.

ABSORPTION. Loss of energy by a radio-wave due to absorption by the ionosphere in the case of an ionospheric wave, and absorption by the ground, hills, buildings, forests and so forth, in the case of ground waves.

When the electrons in an ionized layer are set in motion by a wave, collisions will occur between the electrons and the ionized gas molecules. At high frequencies, the average time between collisions is long compared with the period of the wave, so that the effect of the collisions is not very important, and the effect of these collisions can be regarded as providing a damping-force proportional to the velocity of the electrons but tending to impede their motion. When the frequency is high, the damping-force is small and the energy-loss while the wave is in the layer is small.

As the frequency is reduced, however, the damping-force increases and the absorption becomes greater, until the frequency of the wave corresponds to the average time of collisions in the layer. At this frequency a resonance effect takes place and the absorption of energy from the wave becomes enormous. The frequency at which this heavy absorption takes place varies according to the state of ionization of the layer, each layer having a critical wave band in which the absorption is so high as to make reception by means of the ionospheric wave completely unreliable.

The critical wave band of the E-LAYER (q.v.) is approximately 150–350 metres, and that of the F-LAYER (q.v.) is 8–12 metres. It is thus evident that the best results are obtainable with the higher frequencies, provided that they are outside the limits of the critical wave bands.

Absorption or attenuation of the ground wave depends, in a rather complex way, on the conductivity of the earth's surface and on its relative permittivity, both of which vary for different kinds of soil and for different weather conditions. For the lower frequencies, it is the conductivity which is more important; the higher this is, the lower is the attenuation. For high- and very high-frequency waves, the relative permittivity becomes more important; the higher it is, the less the attenuation. Thus for all frequencies the ground wave is attenuated less over sea than over land, and the attenuation increases with frequency. For example, the ground-wave range of the G.P.O. station at Rugby, operating on a frequency of 16 kc/s, is several thousand miles; whereas a station using a frequency of 75 Mc/s will have a ground wave of only a few miles. The ground wave undergoes attenuation because it induces alternating e.m.f.s in the earth and, as the earth has a finite resistance, there must be a loss of power and current, energy thus dissipated being supplied by the wave itself. See CONDUCTIVITY, GROUND RAY, IONOSPHERE, IONOSPHERIC RAY, RELATIVE PERMITTIVITY.

ABSORPTION MODULATION. Amplitude modulation in which the amplitude of a carrier wave is varied according to the power absorbed from it in a variable resistance, the value of the resistance being controlled by the modulating wave. See ABSORPTION MODULATOR, LINEAR MODULATION, VARIABLE-RESISTANCE MODULATION.

ABSORPTION MODULATOR. Modulator in which the anode slope-resistance of a valve is varied by the modulating wave and absorbs more or less power from the carrier wave. As the voltage applied to the grid of a valve is varied by the modulating wave, the valve absorbs more or less power from the carrier source connected between anode and cathode. Thus the amplitude of the carrier wave is varied by the modulating wave. The method is obsolescent, however, because, with deep modulation, modulation distortion is intolerable for most purposes. See MODULATION DEPTH, MODULATION DISTORTION.

A.C. Abbreviation for ALTERNATING CURRENT.

ACCELERATOR. Electrode in a cathode-ray tube, and sometimes referred to as the "anode," which is normally at a positive potential with respect to the cathode. Successive accelerators are employed to provide not only successive accelerations of the electrons leaving the cathode, but also to provide a method of focusing the electrons into a narrow beam which will form a sharply defined spot at the screen.

The so-called gun assembly of the modern cathode-ray tube usually consists of the cathode, the grid and three accelerators, as shown in Fig. 1, the potential differences between the cathode and the other electrodes being approximately:

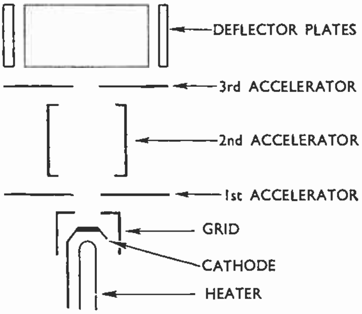


Fig. 1. Diagrammatic representation of the electrodes of a cathode-ray tube, showing arrangement of accelerators.

Grid, 15–50 volts negative;
1st Acc., 300 volts positive;
2nd Acc., 1,000 volts positive;
3rd Acc., 2,000–5,000 volts positive.

There is thus a difference of potential between the first and second accelerators of about 700 volts, and between the second and third of several thousand volts.

The electrons are, therefore, speeded up on each stage of their journey as they come under the influence of the increasing positive potentials. This succession of potential increases has, however, a further effect whereby the electron beam is focused. See ELECTRON LENS.

ACCELERATOR GRID. See SCREEN GRID.

ACCEPTOR CIRCUIT. Series-tuned circuit so connected in relation to other parts of a circuit that it reduces a voltage to a low value at a particular frequency at a particular point in the circuit (Fig. 2). A series-tuned circuit has its lowest impedance at a certain frequency. This is the frequency at which the inductive reactance of the inductor has the same numerical value as the capacitive reactance of the capacitor. Thus the acceptor circuit, having a relatively low resistance at a certain frequency, reduces the amplitude of a wave having that frequency to a low value. See RESONANCE, TUNED CIRCUIT, TUNING.

ACCUMULATOR BATTERY. Battery of accumulator cells. See BATTERY.

ACCUMULATOR CELL. Voltaic cell which may be recharged after it is discharged. The e.m.f. produced by voltaic cells is the result of a chemical process which takes place in them. Discharging a cell gradually uses up the chemicals necessary to produce the e.m.f. Thus, depending upon the discharge current and the period for which it flows, there is a limited time during which the cell can produce an e.m.f. at its terminals.

The unique property of the accumulator cell is that the chemical conditions necessary to produce the e.m.f. may be restored without structural alterations to the cell. The cell may be recharged by passing a current through it in the reverse direction to that of the discharging current.

The usefulness of a cell is judged by:

1. Its internal resistance, which should be small.
2. The discharge current that may be taken from the cell without damaging the cell; it should be large.
3. The weight of the cell, which should be low, for a given ampere-hour capacity.
4. The changes in the voltage of the cell during discharge, which should be small.
5. The possibility of restoring the charge without structural alterations to the cell.
6. Ease of installation and maintenance in all sorts of conditions.

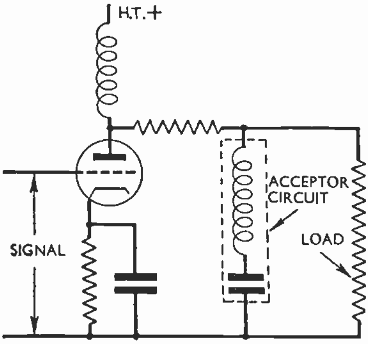


Fig. 2. If the frequency of the wave applied to the grid of the valve is equal to the series-resonant frequency of an acceptor circuit, the voltage across the load is reduced because the circuit has, at this one specific frequency, a comparatively small resistance.

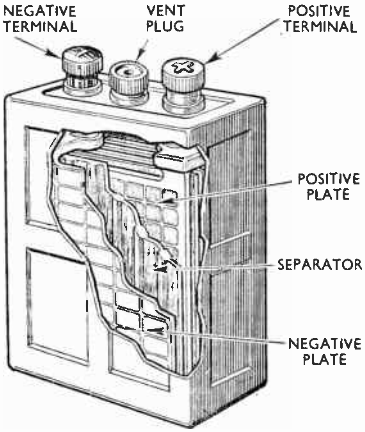


Fig. 3. View of a cut-away small lead-acid type of accumulator cell.

The accumulator cell scores in all the above particulars except 3 and 6; its drawbacks are excessive weight and the fact that it contains acid liable to spill out of the containers. Also, it requires a good deal of attention, for example, the addition of distilled water to the acid from time to time, the greasing of terminals to prevent sulphating, and care that it is not left discharged for long periods.

There are two types of cell. That most commonly used consists of lead plates covered with a weak sulphuric-acid solution; the other type (the Edison cell) uses nickel-hydroxide and iron plates in an alkaline solution.

A small accumulator cell in part

section is shown in Fig. 3. The negative plate is made of lead and the electrolyte is sulphuric acid diluted with pure water. The specific gravity of the electrolyte is 1·24 when the cell is fully charged and has its least internal resistance.

The internal resistance of a cell depends, among other things, upon the area of the plates. In typical construction, the positive and negative plates are interleaved but insulated from one another.

After being fully charged, an accumulator cell of the lead-acid type has a voltage of 2·5 volts, but very soon after a substantial discharge takes place, the voltage falls to 2·0 volts and then remains almost constant during the discharge period. When the cell is discharged, the voltage begins to fall rapidly, and the cell must be charged again to restore its capacity to supply current.

The maximum discharge current that can be taken from an accumulator is limited by the area of the plates and other less important factors. The specified maximum discharge current can be exceeded only at the risk of damaging the cell. Some accumulators are constructed to be able to supply very large currents for short periods. The makers' instructions as they relate to maximum charge and discharge currents should be strictly followed. A cell should never be left in a discharged state for any length of time.

The specific gravity of the accumulator acid varies with the state of charge; it should be at least 1·24 when the cell is fully charged and falls to 1·15 when it is discharged. Some makes of cell have a pointer which moves over a scale marked: "Capacity—full, ¾, ½, ¼, 0." The movement of the pointer is controlled by the specific gravity of the acid.

Lead sulphate tends to form during the discharge period and is recognizable as a white substance liable to coat the plates and the internal connexions. A badly sulphated cell will not give its full rated current, but provided the cell is well looked after and never allowed to remain discharged during long periods, sulphating will not occur. See ACCUMULATOR CHARGING, AMPERE-HOUR CAPACITY, BATTERY CHARGING, HYDROMETER.

ACCUMULATOR CHARGING. Process used to restore the charge in a discharged accumulator battery or cell. The process consists of passing a current through the cell or cells in a direction opposite to that of the discharge current.

If any source from which a direct current can be drawn is used to charge accumulators the positive terminal of this supply must be connected to the positive terminal of the cell to be charged. Moreover, when current flows, a moving-coil ammeter reading the current must show a deflection when the positive terminal of the ammeter is connected to the positive supply terminal and the negative terminal to the positive terminal of the accumulator.

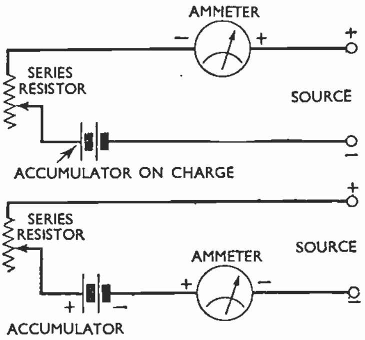


Fig. 4. Basic connexions for accumulator charging. The D.C. source voltage must be greater than the voltage of the fully charged accumulator.

Alternatively, the positive terminal of the ammeter could be connected to the negative terminal of the accumulator and the negative terminal to the negative terminal of the source of supply. If, in either of these conditions,

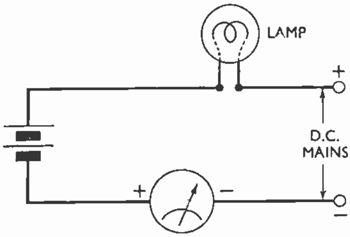


Fig. 5. Connexions for charging a 4-volt accumulator battery of two cells from D.C. mains; charging current is determined by the resistance of the lamp.

the ammeter needle tends to move below the zero, then the voltage of the source is too small and is allowing the battery to discharge a current into the source. Fig. 4 gives the foregoing information in a pictorial form.

Obviously, in order to pass a certain current through a cell in the reverse direction to the discharge current it is necessary to have a supply voltage which is greater than the voltage of the accumulator.

Suppose an accumulator battery of three cells has a voltage of 6 volts and an internal resistance of 0·2 ohm. Suppose also that it is desirable to charge the battery at 5 amp. The source must have a voltage of 6 volts, to overcome the reverse-acting 6 volts of the battery, and sufficient extra voltage to pass 5 amp. through 0·2 ohm. This is 5 amp. × 0·2 ohm = 1·0 volt, so that 6 + 1 = 7 volts are required.

Almost as soon as a charging current flows, the accumulator battery increases its voltage; this may rise, in time, to 2·5 volts per cell, so that a three-cell battery, when on charge, has a reverse voltage of 7·5 volts, and in such a case 8·5 volts will be demanded from the source.

In common practice, as shown in Fig. 4, a resistor is placed in series with the source, and this can be adjusted during charging so that the charging current may be set at a required value. Clearly, power is wasted in this resistance, and this wastage is the greater as the resistance is larger for a certain charging current. The more the source voltage exceeds minimum requirements, the larger the resistance needed.

For instance, using the values given in the foregoing numerical example if only 8·5 volts are required, then if the source volts were 16·5, 8 volts would be dropped in the resistance. The total power required for charging (at 5 amp.) would be 16·5 × 5 = 82·5 watts, or approximately $\frac{1}{12}$ of a unit. At, say, 2d. per unit the cost of charging would be $\frac{1}{6}$d. per hour, or nearly 2d. for a 50-Ah. accumulator.

When 4- or 6-volt accumulators are charged from D.C. mains of the order of 100 to 200 volts, the usual practice is to put lamps in series with the mains and the accumulators (Fig. 5). The lamps must have a voltage rating to match the mains voltage, for example, a 200-volt lamp is used for 200-volt mains. Provided the voltage of the accumulator battery is much less than that of the mains, the charging current in amperes is given by dividing the watt rating of the lamps by the mains voltage in volts. The power taken from the mains is a little less than the power rating of the lamps.

With A.C. mains, it is usual to

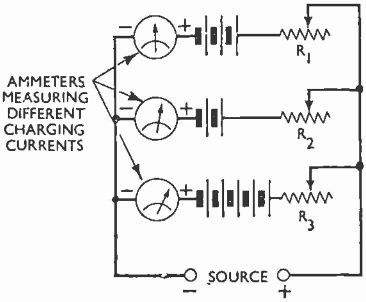


Fig. 6. Method of charging accumulators simultaneously from a single source, but at different rates, by suitable adjustment of R_1, R_2 and R_3.

charge accumulators through a transformer and rectifier; the voltage at the secondary of the transformer is reduced from the mains voltage to a value sufficient to pass current through a rectifier and an accumulator battery of specified voltage. There are many makes of these charging units on the market.

A motor-generator set may also be used to convert the mains power, whether the supply is A.C. or D.C., to a suitable form for the economic charging of accumulators. Fig. 6 shows how several different accumulator batteries, requiring different charging currents, may be simultaneously charged.

Attention should be paid to the following points during the charging of accumulators:

1. If the accumulators are not equipped with some device indicating their state of charge, the fact that they are nearly fully charged will be shown by strong gassing at the plates. The vent plugs should be left undone during charging and naked lights ought not to be brought near the accumulators.
2. Petroleum jelly should be coated over terminals to prevent sulphating.
3. Some of the electrolyte will be lost during the charging period. The loss should be made up by adding distilled water, not dilute acid, provided the specific gravity has the correct value.
4. An hydrometer should be used to test the specific gravity of the liquid if other means of recording it, such as pointers moving over a scale or floats in the acid, are not embodied in the accumulator.

A.C. GENERATOR. Generator for the production of alternating current.

ACORN VALVE. See MINIATURE VALVE.

ACTIVATION. Process in which the cathode of a valve is so treated that it gives the greatest possible emission. Cathodes, whether of the filament or indirectly heated type, are made from tungsten, thoriated tungsten and metallic oxides. The tungsten filament does not require activation, but thoriated tungsten is activated by FLASHING (q.v.). The process of glowing thoriated tungsten consists in keeping it at a temperature of 1,600 deg. K. in a hydrogen atmosphere; this causes carbonizing of the tungsten.

Oxide-coated cathodes are glowed for several minutes at 1,500 deg. K. After glowing, a strong positive anode potential is applied. The emission increases to a fixed limit and then the electrostatic field and temperature are reduced.

Activation is a delicate process subject to many possible variations which cannot be covered in this generalized description. See EMISSION.

ACTIVE AERIAL. Aerial directly connected to a sender or receiver, as distinct from a reflector or director element, which is not so connected. See PASSIVE AERIAL.

ACTIVE COMPONENT. Component which is in phase with a vector used for representing an alternating phenomenon.

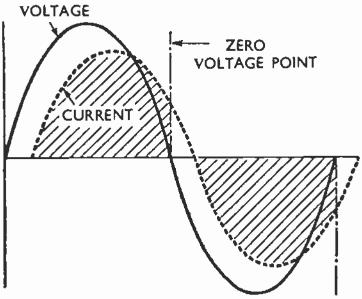


Fig. 7. When current and voltage are "out of step" in an A.C. circuit, that part of the current wave which coincides with the voltage is called the active current or active component (here shown shaded).

In the above graph (Fig. 7) the active component is shown shaded. See ACTIVE CURRENT, ACTIVE VOLT-AMPERES, ACTIVE VOLTAGE.

ACTIVE CURRENT. Component of the total current in an alternating circuit which is in phase with the alternating voltage. The power in the circuit is found by multiplying these two quantities together. See ACTIVE COMPONENT.

ACTIVE MATERIAL. In an accumulator cell, material the chemical condition of which changes during charging and discharging periods.

ACTIVE VOLTAGE. Component of the voltage in an alternating circuit which is in phase with the current flowing in the circuit. See ACTIVE COMPONENT.

ACTIVE VOLT-AMPERES. Product of the active current and the voltage in an A.C. circuit. In other words, a true measure of the wattage or available power in the circuit, making due allowance for the out-of-phase effects between current and voltage due to the inductive or capacitive nature of the load. See ACTIVE COMPONENT, POWER FACTOR.

ACTUAL LEVEL. Ratio of power at any specified point in a circuit to 1 mW, this ratio being expressed in decibels. Thus, the output from an amplifier might be 100 mW; the ratio of 100 mW to 1 mW is 20 db., and so the actual level in this case is 20 db. If the power is less than 1 mW, the ratio is usually written with a minus sign; thus a power of 0·5 mW is very nearly −6 db., that is to say, the actual level is −6 db. See DECIBEL, POWER, RELATIVE LEVEL, TEST LEVEL.

ADAPTER. Device by whose agency a plug of one size or type may be inserted into a socket of a different size or type, or several plugs may be connected to one socket. Adapters are commonly used as auxiliaries to power-supply plugs and sockets so that several current-using devices can be connected to one socket outlet. They consist of one set of plug contacts in electrical connexion with one or more sets of socket contacts, the whole being mounted in an insulating body. See PLUG AND SOCKET.

ADCOCK DIRECTION-FINDER. Direction-finder employing spaced vertical aerials feeding into a common receiver via a goniometer and provided with some means of reducing the effects of horizontally polarized waves and the errors resulting from them. See SPACED-AERIAL DIRECTION-FINDER, U-TYPE DIRECTION-FINDER.

ADMITTANCE. Quantity which is the reciprocal of impedance, and is thus a measure of the facility with which a current can flow in a circuit under the pressure of a given electromotive force. See IMPEDANCE.

AERIAL. Device from which energy can be radiated in the form of electromagnetic waves; or device by which energy can be picked up from electromagnetic waves. The most familiar type is doubtless the single elevated wire, earthed at one end. If it is suspended vertically, it responds equally to vertically polarized waves reaching it from any direction; this is the classic form of omni-aerial. It resonates in a manner depending on the relation between its physical length and the wavelength of the signal radiated or picked up. If the conductor is earthed at one end it resonates at the frequency for which the aerial length is equal to a quarter wavelength. See QUARTER-WAVE AERIAL.

This is the normal behaviour of such an aerial; in practice, it is customary to use a conductor somewhat shorter than a quarter of the shortest wave likely to be received and to bring it into the resonant condition by loading with inductance and, possibly, capacitance. An exception occurs when an aerial is required to cover a considerable range of frequencies; if made to resonate in the quarter-wave mode at the highest frequency the aerial would be so short that it would be inefficient at the lower frequencies.

In practice, the aerial should be long enough to act as a quarter-wave system over the medium- and lower-frequency range, and to respond at or near one of its harmonics for any higher frequency. Whenever the aerial length is some suitable multiple of a quarter-wave, it can respond in this way. Fig. 8 shows two of the possible voltage distributions in a simple vertical wire which is too long to resonate as a quarter-wave aerial for a particular signal.

To this general class belong such standard types as the inverted-L and inverted-T aerials, in which a horizontal portion is added to provide some localized capacitance high above ground, or endow the aerial with a degree of directivity to suit a specific case. The quarter-wave element, earthed at the foot, is also used as a constituent part of some forms of directive array; here, the massing together of a number of elements produces the required directivity. Such aerials are extensively used for sending purposes on low and medium frequencies.

Another form of aerial which, although earthed, works in a basically different manner, is that sometimes called a wave aerial. A given element of this kind is often several wavelengths long and does not tend to resonate in a fixed pattern of voltage nodes and antinodes. A simple instance is the Beverage aerial, which normally consists of a long single horizontal wire, a few feet above the ground, earthed at one end through a receiver and at the other through a resistor of value equal to the surge impedance of the line, that is, of the wire regarded as a single-wire feeder with earth return.

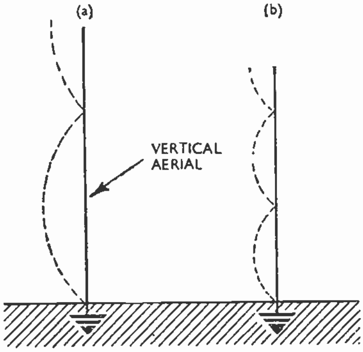


Fig. 8. Possible voltage distributions in a vertical aerial responding to frequencies higher than its fundamental; in (*a*) the aerial height is 3/4 and in (*b*) 5/4 of the wavelength.

Such an aerial delivers large signals to the receiver because, in broad terms, the induced currents travel faster in the wire than in the ground and create a phase difference causing a voltage to be set up between the end and earth. This type of aerial is strongly directive, receiving best from the direction of the end remote from the receiver. In practice, it may be elaborated in numerous ways, as by the addition of extra wires in parallel, or, on a slightly different plan, by the use of a diamond-shaped system of non-resonant elements as in the RHOMBIC AERIAL, V-AERIAL (q.v.).

Another general class of aerials employs elements, singly or grouped in arrays, which are not earthed. In most cases, the elements are arranged to behave as half-wave resonators (see HALF-WAVE AERIAL); hence this form of aerial is mainly used at those higher frequencies at which a half-wave element is of practicable size, and is widely employed for the very high frequencies from, say, 30 Mc/s to 3,000 Mc/s.

These are examples of what is called the open aerial, to distinguish it from the loop, which forms a closed circuit with its associated tuning capacitor. For sending, the open aerial has the obvious advantage that its magnetic and electric fields are spread out to embrace as much space as possible; the closed loop, with its restricted fields, is not, therefore, used for sending. Since the aerial is essentially a reversible device, one can safely argue that what is inefficient for sending is not good for receiving, and, in a sense, this is true of the loop; it is in fact inefficient as a pick-up device, but high-

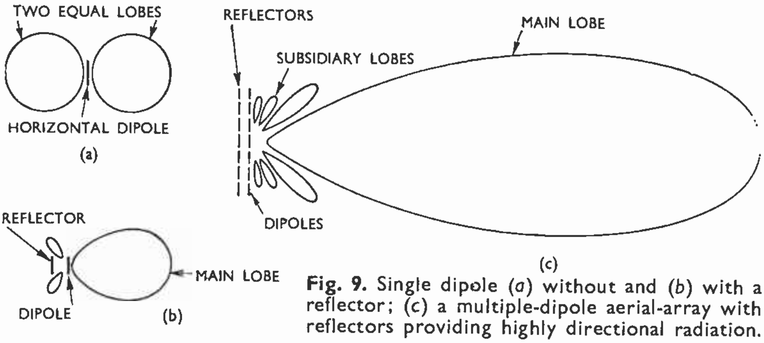


Fig. 9. Single dipole (*a*) without and (*b*) with a reflector; (*c*) a multiple-dipole aerial-array with reflectors providing highly directional radiation.

ly sensitive receivers have made this of little importance.

On the other hand, the loop is highly directive, and this property is often sufficiently valuable to make its use worth while. Moreover, its losses are under the control of the designer and can be made somewhat lower than those of the average open aerial generally used for broadcast reception. The loop therefore gives some improvement in selectivity.

Here, somewhat oddly, its major weakness—low efficiency in extracting energy from passing waves—is indirectly a virtue. Low efficiency as a radiator, and therefore as a pick-up device, implies low radiation resistance: low radiation resistance means very little damping and high selectivity (see AERIAL RADIATION-RESISTANCE).

The directive properties of the loop are employed in the obvious way for direction-finding; but they are also useful in minimizing pick-up of interfering signals or random noise coming from a definite direction. In such circumstances, the loop, correctly used, may give considerable relief. This is due to a simple but often forgotten characteristic: although the setting for maximum signal from a given station is broad and covers a wide swing of the loop, the minimum position is narrow and well defined. If, therefore, a loop is set to pick up the minimum of a particular interfering signal, there is a good prospect that the wanted station will still be heard, since, for this, the loop need not be set accurately to a definite bearing.

These are the basic elements of which nearly all the more elaborate composite aerial systems are composed. The broadside array, for instance, is commonly a collection of half-wave dipole aerials, either in a tier, if it is desired to produce a beam which is compressed in the vertical direction; or a horizontal row, if the beam is to be narrow in the horizontal plane; or a row of tiers, when the beam is to be focused narrowly in both planes.

Again, there are various elaborations of the non-resonant wave aerials such as the rhombic; composites consisting of duplicated or triplicated basic elements are also used, but without change of principle.

More detailed information of specific types may be found under the appropriate headings. See ACTIVE AERIAL, AERIAL-ARRAY, AERIAL GAIN, AERIAL RESISTANCE, BROADSIDE ARRAY, CAGE AERIAL, CONICAL AERIAL, CONICAL-HORN AERIAL, DIAMOND AERIAL, DIRECTIVE AERIAL, FRANKLIN AERIAL, HALF-WAVE AERIAL, INVERTED-L AERIAL, INVERTED-V AERIAL, LOOP-AERIAL, MAST AERIAL, PASSIVE AERIAL, STANDING-WAVE AERIAL, T-AERIAL.

AERIAL-ARRAY. Assembly of aerial elements so arranged and spaced as to produce directional effects. Each element is commonly, though not invariably, a complete aerial in itself, as in an assembly of half-wave dipoles connected to a branching feeder system.

Polar diagrams showing the horizontal patterns of radiation from a dipole with and without a reflector are given in Fig. 9; a figure-of-eight pattern is produced from a normal horizontal dipole (a), whereas a directional lobe is produced by placing a reflector behind the dipole (b).

A more pronounced directional effect is obtained by using an array consisting of several dipoles placed end to end with a corresponding series of reflectors mounted behind them (Fig. 9c). See BROADSIDE ARRAY, CURTAIN ARRAY, END-FIRE ARRAY.

AERIAL CURRENT. Maximum r.m.s. value of radio-frequency current flowing in an aerial when signals are being sent or received.

AERIAL EFFECT. Synonym for ANTENNA EFFECT.

AERIAL FEED-IMPEDANCE. Effective impedance of an aerial as measured at the point where energy is fed into it, or taken from it. For example, the impedance of a half-wave dipole at its open centre point when current-fed. See CURRENT-FED AERIAL.

AERIAL GAIN. Relative term denoting the ratio of the efficiency of a given aerial to that of an assumed standard—usually taken to be a single half-wave dipole. The gain is commonly expressed as the ratio of the powers delivered to a receiver by the two aerials, other factors being kept constant.

AERIAL RADIATION-RESISTANCE. That fraction of the total radio-frequency resistance which arises from the radiation of energy by the aerial. See AERIAL RESISTANCE.

AERIAL RESISTANCE. Equivalent radio-frequency resistance of the complete aerial-system measured at the point where power is put in or taken out. This resistance is made up of two components: the radio-frequency resistance of the conductors, which includes the effect of losses in dielectrics; and another resistance which is postulated as accounting for the energy which in fact is lost as radiation from the aerial. The ratio of radiation resistance to total resistance is some measure of the efficiency of an aerial-system and in a good aerial the radiation resistance may form a substantial fraction of the total.

AERIAL-SYSTEM. Aerial of any type with its masts or other supports and connecting feeders regarded as a complete assembly.

AEROPLANE EFFECT. Direction-finding error due to the presence of a horizontally polarized component in the radiation of an elevated sender, such as an aircraft with a trailing-wire aerial (see AIRCRAFT AERIAL). Similar errors may be produced when waves initially vertically polarized acquire an obliquely or horizontally polarized component during propagation. See POLARIZATION ERROR.

AETHER. Synonym for ETHER.

A.F. Abbreviation for AUDIO FREQUENCY.

AFTER-GLOW. Persistence of luminosity of the screen of a cathode-ray tube after the electrons have stopped striking it; see also PHOSPHOR. The impact of electrons on the substances used to form the screen of a cathode-ray tube causes the particles in the screen to fluoresce. This fluorescence should cease immediately impact ceases, but usually a certain amount of phosphorescence occurs and the screen continues to glow, this phenomenon being termed after-glow.

The period of after-glow varies from a matter of a few milliseconds to several seconds according to the substance used for the screen and the number and speed of the electrons striking it. In some uses of the cathode-ray tube (see RADAR), long after-glow is an advantage, whereas, in an oscilloscope and in television, the period of lag before illumination dies away should be as short as possible.

A.G.C. Abbreviation for AUTOMATIC GAIN-CONTROL.

Ah. Abbreviation for AMPERE-HOUR(S).

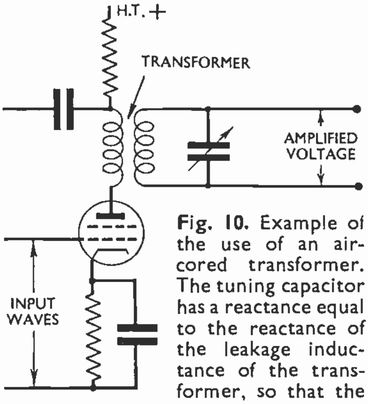


Fig. 10. Example of the use of an air-cored transformer. The tuning capacitor has a reactance equal to the reactance of the leakage inductance of the transformer, so that the voltage across the secondary has a maximum value for a particular frequency applied to the primary winding.

AIR CAPACITOR. Form of capacitor having air as the dielectric. See FIXED CAPACITOR, VARIABLE CAPACITOR, TRIMMER.

AIR CONDENSER. Synonym for AIR CAPACITOR.

AIR-COOLED ANODE. Anode external to the bulb of a valve and surrounded by fins on to which air is blown. See ANODE DISSIPATION, COOLED VALVE, WATER-COOLED VALVE.

AIR-COOLED VALVE. Valve in which the bulb is made of silica glass and which is cooled by air blown on to the glass. Such valves have a rated anode dissipation of from 1 to 3 kW. See AIR-COOLED ANODE, ANODE DISSIPATION, COOLED VALVE, WATER-COOLED VALVE.

AIR-CORED COIL. See AIR-CORED INDUCTOR.

AIR-CORED INDUCTOR. Inductor having a core of non-conducting, non-magnetic material. Many inductors for use at radio frequencies are of this type because, apart from certain dust-cored inductors, the benefits of a high-permeability core which are attainable at low frequencies are far outweighed by the losses introduced at radio frequencies. See FIXED INDUCTOR, INDUCTOR.

AIR-CORED TRANSFORMER. Transformer in which no iron is used to increase the mutual inductance between the windings. Air-cored transformers are used when the waves passing through them are of such a high frequency that the losses in iron cores would be intolerable. Fig. 10 shows an air-cored transformer as used in typical practice; the tuning capacitor is given a value such that it will resonate with the inevitable leakage inductance of the transformer, to give the required voltage gain.

In such a case, the frequency band over which the transformer is efficient is limited, but often suffices in the reception of modulated-wave signals. See IRON LOSS, LEAKAGE INDUCTANCE, MUTUAL INDUCTANCE, TRANSFORMER.

AIRCRAFT AERIAL. Aerial specially adapted to use in the air, either by its construction or its electrical properties. The classic form of aircraft aerial is the long, trailing wire, and this was widely used prior to about 1940. Such an aerial may be up to 250 ft. long, weighted at the end and paid out or wound back with the aid of a winch. This form of aerial has substantial electrical advantages, but the increasing speeds of all aircraft and the need for manoeuvrability in military types have served to emphasize its practical drawbacks.

The present general tendency towards shorter waves has involved the adoption of smaller aerials, mostly dipoles or quarter-wave aerials of rod construction, or of special radiators for centimetric wavelengths. Where medium frequencies are still used, the aerial is most likely to be a stretched wire attached to the structure of the aircraft. For direction-finding purposes, a rotating loop-aerial with remote control may be carried, often in a streamlined casing so that it may be fitted externally. See AIRCRAFT RADIO EQUIPMENT.

AIRCRAFT RADIO EQUIPMENT. Radio apparatus carried in aircraft. The objects of radio in aviation can

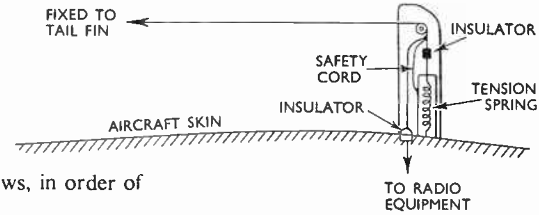


Fig. 11. Fixed-aerial installation for aircraft. The aerial is kept taut by a tensioning spring, and a safety cord is incorporated.

be summarized as follows, in order of importance:

1. Navigational service, i.e. direction-finding and approach-landing systems.
2. Giving meteorological information.
3. Passing instructions to the captains of aircraft.
4. Routine messages dealing with organization.
5. Public correspondence (radio-telegrams).

In addition there are, of course, various radar devices, most of which come within category 1 above, e.g., Gee, H_2S, Loran (see PRIMARY RADAR. RADAR).

The frequencies allocated for civilian aviation in Europe are between 255 and 290 kc/s, and between 320 and 365 kc/s in the medium-frequency band. These frequencies are used for traffic between stations, navigation beacons, and for passing meteorological information. Higher-frequency bands are used for passing traffic and meteorological messages at long distance. The very high-frequency (V.H.F.) bands (roughly between 30 and 40, and 100 and 150 Mc/s) are used for landing and approach beacons, as well as for short-range telephony communication.

A suitable frequency coverage for a general-purpose aircraft installation is approximately as follows: 200–500 kc/s (1,500–600 metres); 3–5·5 Mc/s (100–54·5 metres); 5·5–10 Mc/s (54·5–30 metres).

Bonding. The earth on an aeroplane is formed by arranging electrical continuity through all the metal in the structure. This is called bonding. On a modern aeroplane of all-metal construction, this is a simple process, as there are relatively few metal parts electrically discontinuous from the main structure. The control surfaces (ailerons, flaps, elevators and rudder) are bonded across their hinges and, if the engines are mounted on rubber suspension brackets, these are also bonded. An aeroplane of wooden construction obviously presents greater bonding difficulties.

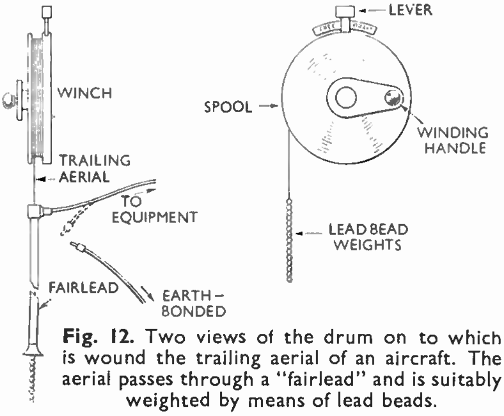


Fig. 12. Two views of the drum on to which is wound the trailing aerial of an aircraft. The aerial passes through a "fairlead" and is suitably weighted by means of lead beads.

A modern commercial aircraft is fitted with at least six aerials: a fixed aerial, a trailing aerial, a direction-finding (D.F.) loop, a vertical or whip main-beacon aerial for beam approach (B.A.), a horizontal dipole for marker beacons and a second whip aerial for V.H.F. radio telephony.

The fixed aerial, used with the main W.T. (wireless telegraphy) equipment, is usually made from stainless-steel wire, and is normally 60–70 ft. in length. It is fixed between a stub mast situated above the main equipment and the tail fin of the aircraft. Fig. 11 illustrates a typical fixed-aerial installation and shows the method used to keep the aerial taut by means of a spring, and safeguarded by a check-cord or safety wire.

The trailing aerial, which is now being used to a decreasing extent, has a maximum length of about 250 ft., but the length in use can be increased. It is attached to a moulded plastics drum by means of a cord, and is weighted by means of lead beads (about 1½ lb. in weight). The aerial wire is brought into the aircraft through a "fairlead" which consists of a Paxolin tube passing through the aircraft skin (Fig. 12).

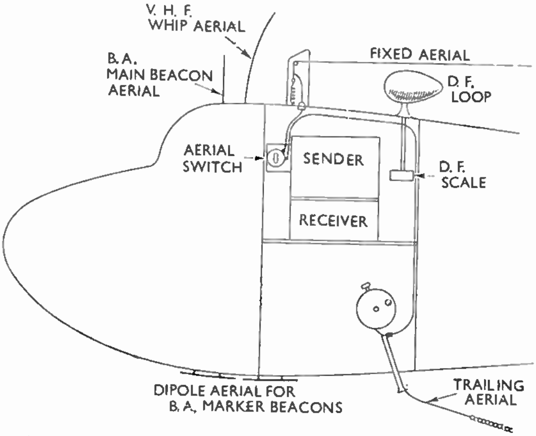


Fig. 14. Example of the lay-out of aerials in a large aircraft. Aerial arrangements are often more complex, however, owing to the number of radio/radar devices used in modern airliners.

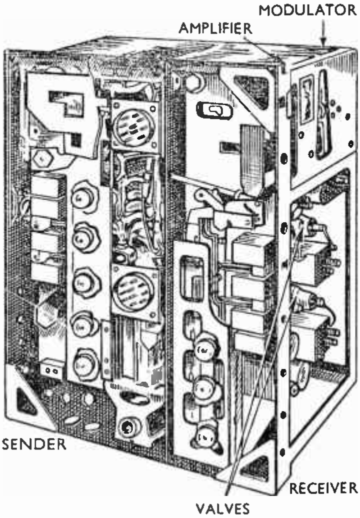


Fig. 13. V.H.F. sender and receiver as used for short-range R.T. communication. The external connexions are made to two ten-point sockets.

There are two B.A. aerials. The main beacon-receiver aerial is usually of the whip type. The marker-beacon aerial is a dipole and is usually mounted beneath the fuselage on small stand-off insulators.

A whip aerial is generally used for the V.H.F. radio-telephony equipment, but this is sometimes replaced by a short, stub aerial. It is usually mounted in close proximity to the V.H.F. sender/receiver.

Fig. 13 shows a V.H.F. sender/receiver unit for short-range radio telephony, and Fig. 14 a typical arrangement of aerials on a large aircraft.

Electrical interference on aircraft is attributable mainly to the ignition system of the engines. The usual method of suppression is to screen all parts of the ignition system completely. This means that the magnetos are enclosed in earthed metal cases, H.T. and L.T. leads are screened cable with the metal braiding earthed, and the sparking-plugs are specially designed with earthed metal screens.

The charging circuits may cause interference if a constant-voltage regulator of the vibrating-contact type is used. Suppression can be achieved by screening or by the use of chokes and capacitors arranged as filter circuits.

Interference may also occur from the electric motors used to operate the retracting undercarriage, flaps, de-icing pumps and windscreen wipers. Filter circuits are normally employed to suppress it.

Typical Aircraft Equipment. The Marconi AD.87B/8882B aircraft radio equipment (Fig. 15), which is better known as the T.1154/R.1155, is typical of modern practice in large commercial and Service aircraft.

Transmission and reception on both short and medium waves are provided, and continous, or A1, waves (C.W.), modulated continuous, or A2, waves (M.C.W.) or radio telephony can be used. Direction-finding facilities are available on the medium-wave bands of the receiver by the use of a rotating loop-aerial, with facilities for visual and aural D.F. and homing.

The *sender* covers the following four frequency bands:

Range 1, 16·7–8·7 Mc/s.
Range 2, 8·7–4·5 Mc/s.
Range 3, 4·5–2·35 Mc/s.
Range 4, 500–200 kc/s.

The power supplies for the sender and receiver are obtained from two motor generators which in turn are supplied from an engine-driven generator. The L.T. power unit supplies 6·3 volts for heating all the receiver and sender valves, and approximately 220 volts for the anodes of the receiver valves. The H.T. motor-generator supplies 1,200 volts for the anodes of the sender valves. The starting relay of the H.T. power unit is energized by the L.T. output of the L.T. power unit so that H.T. cannot be applied to the sender before the filaments are alight.

The power consumption of the equipment is approximately 250 watts when in the "receive" and 500 watts in the "send" position. The R.F.

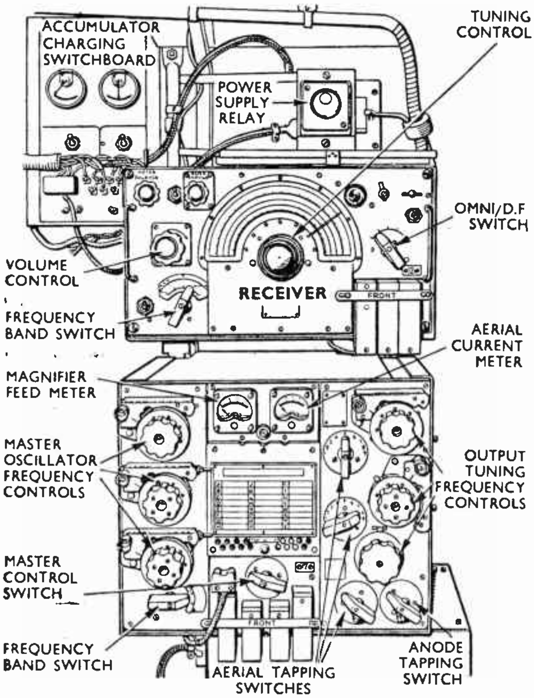


Fig. 15. Marconi sending and receiving installation for general communication and direction-finding. The sender measures 15¾ in. × 16¾ in. × 11 in. and the receiver 10 in. × 16½ in. × 11½ in. The total weight of the complete installation is approximately 190 lb.

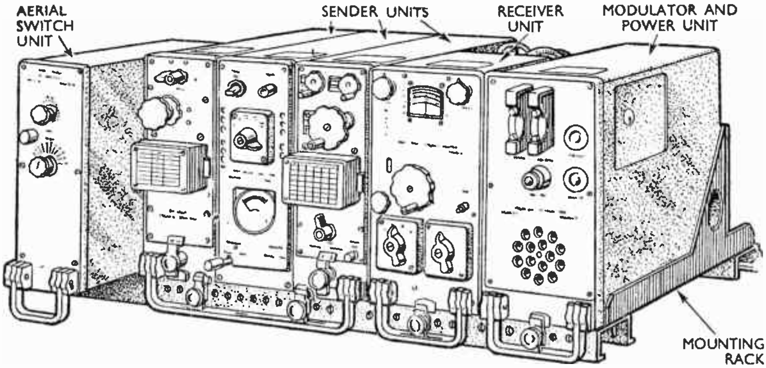


Fig. 16. Lightweight communications equipment mounted on the standard airborne racking. The aerial-switch unit is shown partly withdrawn to indicate the facility with which individual units may be removed or interchanged as required.

output is 50–80 watts on C.W. and a quarter power on R.T. and M.C.W.

A fixed aerial is used for H.F. and a trailing aerial for M.F. These are connected to the sender and receiver by means of a specially designed switch with the following five positions: "normal," "D.F.," "M.F. on fixed aerial," "H.F. on trailing aerial," and "earth."

The sender circuit consists of a master oscillator stage in which an indirectly heated triode is used as a Hartley oscillator, this being capacitance-coupled to a power-amplifier stage which comprises two directly heated pentodes in parallel. A second indirectly heated triode is used as a 1,200-c/s oscillator to provide side-tone on C.W. This valve is used as a modulator for radio telephony and C.W.

A master switch for controlling the sender is positioned centrally at the bottom of the front panel and is marked "off," "STD.BI," "tune," "C.W.," "M.C.W.," "R.T."

The *receiver* is an efficient 10-valve superheterodyne covering the following ranges:

1. 18·5–7·5 Mc/s.
2. 7·5–3·0 Mc/s.
3. 1,500–600 kc/s.
4. 500–200 kc/s.
5. 200–75 kc/s.

The fixed aerial is used for ranges 1 and 2, and the trailing aerial for ranges 3, 4 and 5.

The receiver has a number of special features, some of which can be recognized from the named parts and controls illustrated in Fig. 15.

The valves are (1 and 2) D.F. switching valves, (3) R.F. amplifier, (4) frequency-changer, (5 and 6) I.F. amplifiers, (7) A.G.C. and beat-frequency oscillator, (8) detector, output and visual-meter-switching valve, (9) visual-meter-switching valve, (10) tuning indicator. The I.F. is 560 kc/s.

UNIVERSAL RACK MOUNTING. The British aircraft radio industry has agreed to a scheme for standardizing box sizes and finishes and to a new system for the rack-mounting of the boxes. In a complex radio installation, this enables units of equipment produced by different manufacturers to be engineered into a complete radio station of considerable flexibility. It also simplifies the work of aircraft constructors in installing radio equipment.

In the lightweight aircraft radio equipment produced by the Marconi Company there is a strong, lightweight metal rack in which can be clipped any required combination of receiver, sender, power-supply and other units (Fig. 16). A complete assembly, comprising airborne communication sender and receiver, direction-finding equipment and intercommunication amplifier, can be provided within an over-all weight of 120 lb.

Such an installation (Fig. 17) gives the following facilities: transmission and reception on H.F. and M.F.; automatic direction-finding and homing on M.F.; and crew intercommunication.

The miniaturized and standard boxes or instrument units are all 8 in. high, 9½–12½ in. deep and 3, 4, 5 or 9 in. wide according to the particular unit. Known as radio equipment type AD.97/108/7092 the complete installation may comprise almost any combination of the units described in the following notes.

*Transmitter Type AD.*97. This has a normal frequency coverage of 2·5–9·1 Mc/s (120–33 metres) and 320–520 kc/s (938–577 metres), but other frequency ranges are available if specially required.

The sender is arranged for direct control by the radio operator and consists of a central structure containing the valves and two plug-in crystal-controlled tuning units. These tuning units may be arranged as one M.F. (medium frequency) and one H.F. (high frequency) per sender, or two M.F. or two H.F. according to the demands of the service for which the sender is required.

The M.F. tuning unit, carrying four crystals, can be adjusted to four pre-set frequencies, any of which can be selected by means of a switch. The H.F. tuning unit, also fitted with four crystals, may be pre-set on one frequency, the other three frequencies being selected by a switch and the output circuits retuned accordingly.

It is designed for operation on C.W., M.C.W. and telephony. The power output to the aerial circuit is 15–30 watts on continuous waves, according to the aerial characteristics.

*Communication Receiver Type A.D.*108. This has a normal frequency coverage of 2–18·5 Mc/s (150–16·2 metres) and 260–510 kc/s (1154–588 metres), but receivers working on other frequencies are supplied to meet special needs.

The communication receiver is a nine-valve superheterodyne, with facilities for the reception of C.W., M.C.W. and telephony signals. It is arranged for both direct and remote operation. Automatic gain control is provided, together with manual control of radio- and audio-frequency gain. The beat-frequency oscillator for C.W. reception is adjustable over ± 1·5 kc/s.

The normal band width of the receiver is 5 kc/s, but when conditions of reception on C.W. are difficult due to heavy traffic, the selectivity of the circuits may be further increased by switching in a crystal filter to reduce the band width to 1,000 c/s. The receiver contains its own anode power unit operated directly from the aircraft 24-volt D.C. supply, the valve heaters being maintained at 18·9 volts through the regulator unit described below.

Modulator and Power Unit. Anode power for the sender is provided by a rotary transformer, fed with 24-volt D.C. (nominal) from the aircraft supply. The modulator section of this unit is designed to amplify the microphone output sufficiently to provide a signal capable of modulating the sender carrier to a depth of 90 per cent on telephony and to provide modulation at 1,000 c/s for M.C.W. working. In addition, this amplifier provides intercommunication.

A low-gain electromagnetic microphone is employed which, together with the modulating circuits incorporated, provides a high-fidelity communication system.

Radio Station Regulator Unit. This unit is designed to provide a regulated 18·9-volt supply for the heaters of all valves. The regulation is maintained with any D.C. input of between 21·5 and 29 volts. Check meters and arrangements for supply adjustments are brought out to the front panel.

Intercommunication System. An intercommunication system is provided for the radio operator and pilot. Station boxes enable either of them to use the various services provided by the equipment. If required, an additional box can be fitted in the steward's compartment enabling him to communicate with the pilot and radio operator. In addition, provision is made for the station boxes to switch the facilities offered by other items of radio apparatus installed in the aircraft, such as a beam-approach receiver and V.H.F. communication equipment.

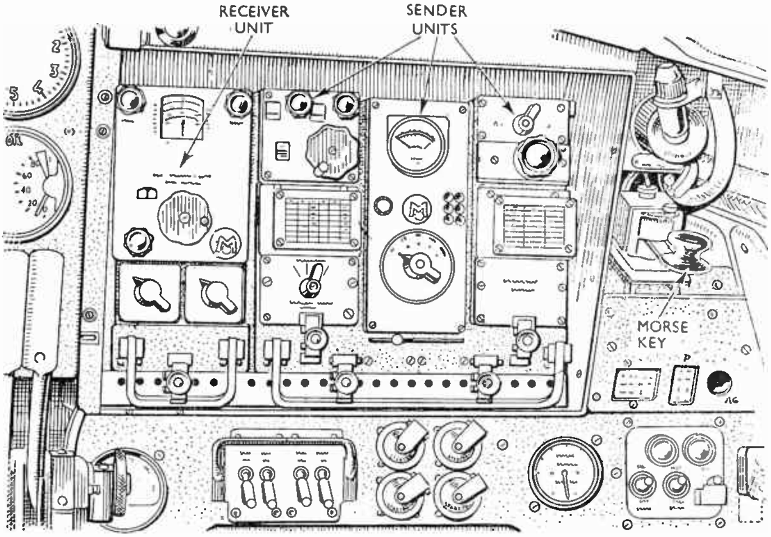


Fig. 17. Equipment, including the Transmitter AD.97, installed in a De Havilland Dove aircraft; it is fitted into the instrument panel on the starboard side.

Aerial Switch Unit. This incorporates the aerial change-over relays, allowing M.F. or H.F. to be used on either a fixed or a trailing aerial. These relays are brought into operation by means of the tuning-unit selector switch mounted on the transmitter panel.

The unit also contains an adjustable inductance for loading the fixed aerial for medium-frequency working. This loading inductance is automatically removed when H.F. is used on the fixed aerial.

*Automatic Radio Compass Type AD.*7092. This is a navigational aid with a normal frequency coverage of 150–2,000 kc/s (2,000–150 metres).

The receiver is an 18-valve superheterodyne receiver which contains its own power unit and is fully remotely controlled, the remote-control box carrying a tuning scale calibrated in kilocycles per second, with all the necessary switching. The usual manual rotation of the loop aerial is superseded by a system of electronic phase-switching, which actuates a special motor driving the loop, and a position repeater which operates the radio compass-bearing indicator. The normal band-width of the receiver is 3·5 kc/s. Increased selectivity can be obtained by the use of crystal filters two additional band-widths of 1,000 c/s and 200 c/s being provided.

While primarily intended for direction-finding and homing, the receiver is also suitable for the normal reception of C.W. and telephony for communication purposes and of radio-range signals.

AIR-GAP. Gap in the magnetic circuit of the core of an inductor. The gap is introduced to prevent saturation of the iron. See INDUCTOR, SMOOTHING CIRCUIT, TRANSFORMER.

AIR-SPACED COIL. Coil for use in an inductor or transformer at radio frequencies, so made that the turns of wire are spaced apart in order to reduce both the self-capacitance of the inductor and the influence of the proximity effect upon its effective resistance and Q-factor. See LATTICE-WOUND INDUCTOR.

ALEXANDERSON ALTERNATOR. Synchronous generator of the inductor type, used for generating high-frequency currents. See SYNCHRONOUS GENERATOR.

ALIGNED GRID. In a valve, a screen grid situated in relation to the control grid so that the wires of the two grids lie on straight lines and perpendicular to the cathode, between cathode and anode. The arrangement ensures that electrons flowing between cathode and anode flow in sheets, with minimum impediment. Moreover, screen-grid current is reduced to a minimum (Fig. 18). The aligned grid is used in the beam tetrode. See BEAM POWER-VALVE, SCREEN GRID.

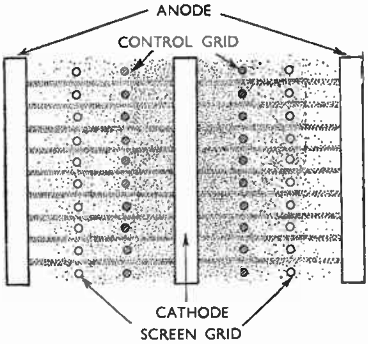


Fig. 18. Diagrammatic illustration of the alignment of the screen grid with the control grid of a valve.

ALL-MAINS RECEIVER. Receiver obtaining all its power supply from the electric mains. The name distinguishes such receivers from the battery-operated type, and, more particularly, from the type wherein anode voltages are derived from the mains, usually via a separate unit containing rectifier and smoothing, while grid bias and filament current are supplied by batteries, a method now less common than formerly.

All-mains receivers intended only for A.C. supplies employ valves with low-voltage heaters taking comparatively large currents, for example, 1 amp. at 4 volts. These are fed from suitable transformer windings, often in paralleled groups.

For D.C. supplies, an all-mains receiver usually embodies special valves whose heaters require a smaller current at a higher voltage, such as 20. These are connected in series, and supplied straight from the mains through a suitable resistor. Such receivers, however, are rare.

A more common type is the universal, designed to work on either A.C. or D.C. mains as required. This uses valves and heater arrangements similar to those just described for D.C. but has, in addition, a rectifier to produce the necessary unidirectional anode voltages when working on A.C. See MAINS UNIT, POWER SUPPLY, RECTIFICATION, SMOOTHING CIRCUIT.

ALL-WAVE RECEIVER. Term somewhat loosely applied to any receiver capable of working on one or more short-wave bands in addition to normal medium- and long-wave broadcast ranges. Typically, such a receiver might cover 10–20 metres, 20–50, 200–550, and 1,000–2,000 metres. This term dates from times when receivers to cover *all* wavelengths in common use were feasible. Recent development of centimetric and millimetric waves has made such designs impracticable, and therefore the term can no longer be taken literally. See BAND SWITCHING.

ALTERNATING CURRENT. Electric current which continually reverses its direction of flow, rising to a maximum in one direction, dropping to zero, then rising to a maximum in the opposite direction. The rapidity with which it does this is called the frequency or "periodicity"; the complete cycle consists of a pulse in one direction followed by a pulse in the other, and the frequency is expressed in cycles per second (c/s).

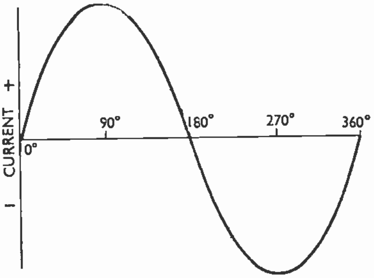


Fig. 19. Graph of one complete cycle of alternating current, showing the usual method of reckoning its timing on an angular scale of 360 deg.

The type of alternating current, or A.C., commonly employed for public supplies in Great Britain has a periodicity of 50 c/s, which means that there are, in fact, 100 pulses of current in each second—50 in one direction and 50 in the other (each pulse is called an alternation; a cycle, therefore, consists of two alternations). For special purposes, alternating currents of higher frequencies, such as 500 and 1,000 c/s are used; the currents involved in the electrical reproduction of speech and music have frequencies ranging from a lower limit of the order of 25 c/s up to an approximate maximum of 10,000 c/s, and those which carry the picture details in television are of still greater frequency range.

The high-frequency currents used in radio communication may alternate as many as a million or a thousand million times every second. All these are alternating currents, but the term is usually reserved for those of comparatively low periodicity which are used for power, lighting and heating purposes.

For an alternating current there is a definite relationship between amplitude (or intensity) and time; the complete cycle is regarded in terms of the 360 deg. of a complete revolution, with the start of the cycle at 0 deg., the halfway point at 180 deg., and the finish at 360 deg. (Fig. 19). Alternating current thus has, at any instant, an intensity proportional to the sine of the angle which corresponds to the particular point in the cycle. This is called the instantaneous value of the current.

To compare a current which is continually changing in value and direction with a steady direct current presents some initial difficulty; for example, to determine the heating effect of an alternating current it is necessary to square its value, as in the case of steady current; but it is difficult to decide what value to take. It is obviously wrong to square the maximum value of the current, because, for a considerable part of the cycle, the current has much smaller values and at times, of course, is zero.

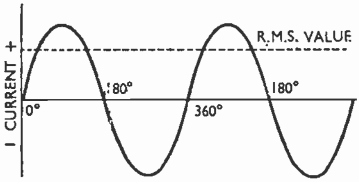


Fig. 20. The value of A.C. at a given instant is equivalent to the sine of the angle corresponding to that instant in the cycle. Heating effect is determined by the r.m.s. value of the current.

The heating effect can be evaluated by taking a number of instantaneous values during a complete cycle, squaring them, determining the average, and finding the square root of the result. The answer gives the value of a steady current which has the same heating effect as the alternating current. It is known as the root-mean-square value of the current (Fig. 20), and whenever a certain value of alternating current is quoted the r.m.s. value is meant. The r.m.s. value of the current or voltage in an alternating circuit is equal to 0·707 of the maximum or peak value; it is sometimes called the "effective" current or voltage. This is only true, however, for currents or voltages of sine wave form.

If the r.m.s. value of an alternating current or voltage is known, it is possible to find the peak value. The peak value is 1·41 times the r.m.s. value. This calculation is often necessary, for example, in determining the peak voltage which will be delivered to the reservoir capacitor of a rectifying circuit. Suppose that a rectifier is to be connected to mains rated at 230 volts; the peak value of the voltage will be 230 × 1·41 or nearly 325 volts, and this is the figure to be considered when choosing a safety rating for the reservoir capacitor which will be connected across the output of the rectifier.

In a D.C. circuit it is simple to work out the power which is being delivered, by multiplying the voltage by the current. But when the supply is alternating, the current and voltage may not be in step (more correctly "in phase"). If the circuit contains inductance, the current will reach its peak value after the peak of voltage has passed, i.e. will "lag." If the circuit contains capacitance the current will "lead" the voltage and will reach its peak value before the voltage.

Thus, to estimate the power in the circuit, the extent of the lag or lead must be taken into account. This is done by multiplying the "apparent" power (the product of r.m.s. current and r.m.s. voltage) by the cosine of the angle of lag or lead. This factor, cos φ, is called the power factor; it is equal to one when there is no lag or lead (that is, when current and voltage are "in phase") and at all other times is less than one. The angle φ of lag or lead is evaluated on the scale of 360 deg. already described.

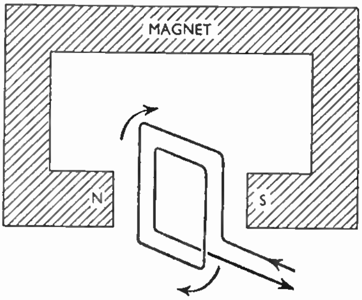


Fig. 21. If a coil of wire is rotated in a magnetic field the voltages induced in the coil rise and fall in the manner of alternating current.

In practical circuits, the power factor is unity only when there is neither capacitance nor inductance in the circuit and the load is pure resistance; or when the values of inductance and capacitance are such as to produce resonance. Extreme cases exist when the circuit contains pure inductance or pure capacitance, without resistance. Voltage and current are then 90 deg. out of phase, cos φ equals zero, and the power is zero. This is the "wattless" condition; it can be approached, but never fully attained in practice. Any physical circuit must contain an amount, however small, of resistance, and if some resistance is present, the 90-deg. phase difference cannot be reached.

Alternating current is simpler to generate than direct current. If a coil of wire is revolved between the poles of a magnet (Fig. 21) the voltages which appear in it by electromagnetic induction are alternating ones; if a direct current is required from the same apparatus, the additional complication of a revolving switching device is needed (this is the commutator of the D.C. generator or dynamo).

Alternating current is more useful than direct current; its great virtue is that its voltage can be varied (changed up or down) by means of a transformer; it can, therefore, be generated at a low voltage, stepped up to a high value for transmission at low loss to some distant point, and there transformed down again to a safe and convenient figure for operating machines, domestic lighting, heating, etc. This process is economical because the transmission of a given amount of power requires a smaller current the higher the voltage is made; a small current needs only a slender conductor to carry it, and a light conductor, insulated to stand high voltages, costs much less than a heavy one insulated for a lower voltage. Insulation is relatively cheap, whereas current-carrying capacity is expensive. Moreover, the power-loss in the case of a small, high-voltage current is less than is economically possible with a large current.

This property of providing any desired voltage by the use of a transformer is one of the most important advantages of alternating current, well exemplified in a radio receiver; here, several different voltages may be needed; for example, to feed valve heaters and for rectification to produce the H.T. supply for the valve-anodes.

Among minor advantages of alternating current are its convenience as a means of synchronizing various devices—the electric clock is an instance—and the ease with which even heavy currents can be broken, that is, switched off by switch-gear. When a large direct current is switched off, it tends to maintain an arc between the separating contact elements of a switch, but when an alternating current is switched off the incipient arc tends to die out as the switch opens, because the current regularly passes through zero value.

ALTERNATOR. Term sometimes used for a synchronous alternating-current generator. See SYNCHRONOUS GENERATOR.

AMMETER. Low-resistance electric-current measuring instrument fitted with a scale calibrated in amperes and multiples or sub-multiples of amperes. Ammeters are of several types: moving-coil, moving-iron, hot-wire, thermo-couple or dynamometer. Ammeters are inserted in series with the circuit, and are frequently shunted by a resistance to permit the measurement of large currents without danger to the instrument.

The basic details of a *moving-coil* ammeter are shown in Fig. 22a. A permanent magnet is fitted with soft-iron pole-pieces. Between the pole-pieces is placed a soft-iron core over which is placed a coil, leaving an air-gap of small dimensions between the core and the pole-faces. A phosphor-bronze spring carries the current to the coil, and a similar coiled spring at the other end of the coil carries the current from the coil. A pointer is pivoted at the centre of the coil and travels over a scale which is calibrated in equidistant divisions.

The coiled springs provide the controlling couple which balances the deflecting couple during the passage of current. When current passes through the coil, the latter tends to rotate about its axis through an angle which is directly proportional to the current flowing through it, owing to the fact that the magnetic field is the same for all positions of the coil.

In the zero position, the springs are not under tension, but, as the coil turns, the springs twist and oppose the motion of the coil, which will come to rest when the torsional pull of the springs exactly balances the electrical torque produced by the current, and the deflection of the pointer is directly proportional, therefore, to the current flowing in the coil.

Moving-coil ammeters can be used for measurement of both D.C. and

A.C., but for A.C. an external rectifier is necessary. Bridge-type copper-oxide rectifiers are generally used.

Moving-iron ammeters, which may be of two types—repulsion and attraction—are more robust but less sensitive than moving-coil ammeters. The basic principle of the repulsion type is illustrated at Fig. 22b. A coil surrounds a pivot which carries both the moving iron and the pointer. When current is passed through the coil the same polarity is induced in both a fixed iron and the moving iron, and repulsion occurs between them, the latter being forced away from the fixed iron, causing the pointer to move.

The movement of the pointer causes the torsion spring to be extended, and this opposes the motion of the pointer, which will come to rest when the tension in the spring exactly counterbalances the electrical torsion set up by the repulsion between the two irons.

In the attraction type of moving-iron ammeter, the fixed and moving elements are replaced by a single soft-iron disc eccentrically pivoted and surrounded by a coil. The disc carries the pointer. Passage of current through the coil causes the disc to become magnetized and move towards the centre of the coil, carrying the pointer with it.

Moving-iron ammeters have scales which are crowded towards the zero, and readings below one-quarter of the maximum tend, therefore, to be inaccurate. These instruments can be used for either D.C. or A.C. work because their action does not depend on direction of current flow. They are liable to be affected by external magnetic fields, but can be safeguarded to some extent by enclosing them in iron cases. Nickel-iron alloy is frequently employed instead of iron as this is less susceptible to hysteresis effects which might otherwise cause inaccuracy in the instrument (see MOVING-IRON INSTRUMENT).

Hot-wire ammeters work on the principle that a stretched wire, usually of platinum silver, will expand if heated. In diagram (c) of Fig. 22 is shown a stretched wire *XYZ* connected at its centre point *Y* to a spring via a pulley. Current passing through the wire causes it to become heated and expand, producing a slackening of the wire. The spring closes to take up the slack, causing a rotation of the pulley, by the movement of the spring wire across it, and a consequent movement of the pointer.

The heat produced in the wire is proportional to the square of the current; the scale is, therefore, not uniform on hot-wire ammeters, the gradations being closer together at the zero end of the scale and well spaced at the other. Such ammeters are somewhat slow in action and their accuracy varies with the temperature of the surrounding air.

They can be used for either A.C. or D.C. work because the heating and expansion of the wire is not dependent upon direction of current flow. They are most frequently employed in radio-frequency A.C. work.

Thermo-couple ammeters depend for their working on the fact that, if the junction of two dissimilar metals in a closed circuit be heated, an e.m.f. is set up between the two metals constituting the thermo-junction.

Fig. 22d shows a loop of wire placed between the poles of a permanent magnet, the lower end of the loop being connected to pieces of steel and Eureka, the junction being heated by the current to be measured which passes through *XY*. The passage of the current heats the junction, and the resultant e.m.f. set up in the loop causes a deflection of the loop between the poles of the magnet and a consequent deflection of the pointer.

Thermo-couple ammeters also can be used for A.C. or D.C. measurements because their action is not dependent upon direction of current flow, but they are most usually employed for radio-frequency A.C. measurements (see THERMO-COUPLE INSTRUMENT).

The basic principle underlying the working of *dynamometer* instruments is that, if current passes through two adjacent wires in the same direction, they will be attracted towards each other. The current to be measured is passed through the two fixed coils, as in Fig. 22e, which are in series with each other and also with a third coil which is free to rotate within the fixed coils. This moving coil carries the pointer and is attached to a spring.

When current is passed through the coils, attraction between them occurs, causing the moving coil to swing towards a horizontal position against the pressure of a spring; the degree of its displacement from the vertical is dependent upon the degree of attraction and, therefore upon the

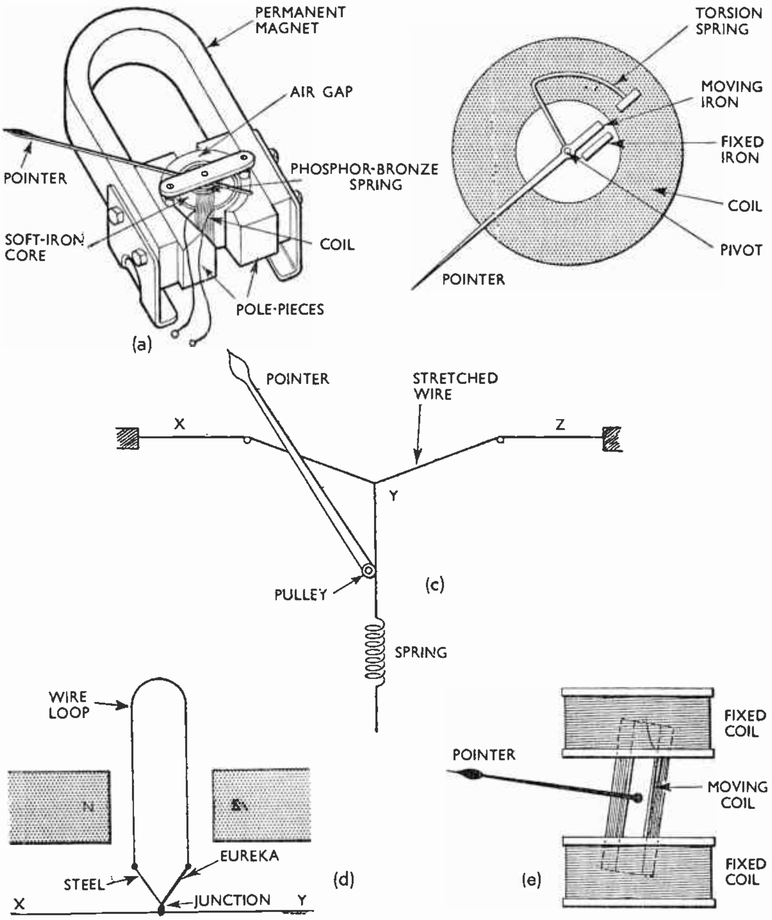


Fig. 22. Principles of operation of various types of ammeter: (*a*) moving-coil; (*b*) repulsion type of moving-iron; (c) hot-wire; (*d*) thermo-couple, and (e) dynamometer. All except (*a*) operate equally well on A.C. and D.C

value of the current that is flowing.

These ammeters can be used for A.C. as well as for D.C. work, for the direction of current flow when A.C. is used will change simultaneously in each coil (see DYNAMOMETER).

AMP. Abbreviation for AMPERE(S).

AMPERE. Unit of volume of electric current, named after a pioneer French physicist. The international ampere is the unit in general use, and this can be defined as the current which will deposit metallic silver at the rate of 0·001118 gramme per second from a solution of silver nitrate by the process of electrolysis. There is also an absolute ampere (see ABSOLUTE UNITS). This is a unit ten times larger, and represents the current which, when passing round a single-turn coil of 1-cm. radius produces a field of 2π gauss at the centre of the coil. See OHM'S LAW, VOLT, WATT.

AMPERE-HOUR. Practical measure of quantity of electricity. It is the amount of electricity delivered by a current of one ampere flowing for one hour. Obviously, the same quantity can be delivered by other combinations having the same product, such as 2 amp. for half an hour.

AMPERE-HOUR CAPACITY. Number giving the current which can be supplied by a cell during a certain time. The number is obtained by multiplying the discharge current in amperes by the time it flows in hours. At the end of the time specified by the ampere-hour capacity, the cell will be discharged. The maximum current that may be taken from the cell must, however, be specified before the ampere-hour capacity can give useful information.

If a cell is said to have a 50-ampere-hour capacity, it might be thought that it could supply 5,000 amp. for one-hundredth of an hour, but a current of this order could not be supplied without damage by a small-capacity cell. If the maximum discharge current were given as 5 amp., then a cell with a 50-ampere-hour capacity would supply 5 amp. for 10 hours or 1 amp. for 50 hours or 100 mA for 500 hours. The maximum discharge current implies a minimum time of discharge; the less the discharge current, the longer the time it flows before the cell is discharged.

The charge taken from a cell is restored by charging. The discharge is expressed in ampere-hours and the charge is similarly expressed, the maximum charging current being specified. Thus, in basic principle, a 50-ampere-hour cell, when fully discharged, can be recharged by passing, say, 5 amp. through it for 10 hours, or 2·5 amp. for 20 hours. In fact, more ampere-hours are used up in charging a cell than can be given up by the cell during discharging. Again, it is essential that the maximum charging current should not be exceeded. The makers always specify maximum charging and discharging currents (see ACCUMULATOR CHARGING).

The ampere-hour capacity unit is applicable to all forms of voltaic cells. A dry cell similarly has a certain ampere-hour capacity, that is, it will supply a certain current for a limited time. Here again, the maximum discharge current must be known before the ampere-hour capacity has any useful meaning.

In some cases, the ampere-hour capacity of a cell is expressed as an ignition rating. This rating is that obtainable when the discharge current is interrupted by a make-and-break system such as is used on internal-combustion engine ignition systems. The ignition rating is naturally greater than the rating which assumes a steady discharge current. See ACCUMULATOR CELL.

AMPERE-TURN. Unit employed in denoting the combined effect of the number of turns in a winding and the density of current flowing therein. Thus if there are 150 turns of wire in a winding and there are 2 amp. flowing round them, the ampere-turn rating of the winding, while thus loaded, is 300.

The magnetizing effect of such a winding is the same as that of one consisting of 100 turns carrying 3 amp., or any other combination having the same ampere-turns.

AMPLIFICATION. Process of increasing the magnitude of an electric current or voltage. Usually, amplification entails the production of a current or voltage which is a magnified copy of another, and is derived from some local source of energy, such as a battery; this local energy is triggered or otherwise controlled by the original current or voltage, but normally flows in a separate and distinct circuit.

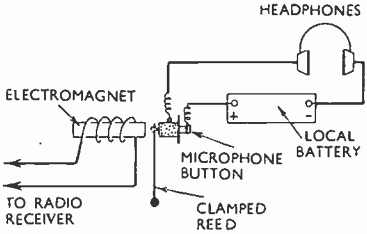


Fig. 23. Principle of the microphone amplifier. Signal currents in the electromagnet vibrate the reed and so cause vibrations in the microphone button.

The process of amplification is fundamental to radio communication; so long as the only energy available in a receiver was the minute amount induced by the incoming signal, reception ranges were severely limited and only headphones could be used.

One of the first attempts to use some kind of relay action to control locally generated energy took the form of a microphone amplifier; a small microphone of special construction was agitated by the movement of an armature, which, in turn, was vibrated by an electromagnet in which the signal currents flowed (Fig. 23).

When the device was correctly adjusted, current taken by the microphone from a battery was modulated in sufficiently close accordance with the signals to yield speech of surprisingly good quality. This amplifier was used extensively during the First World War, but soon after gave place to the triode valve. In one or other of its many forms, the valve is now the universal amplifier in radio communication.

The principle of the valve when used for amplification is basically simple: small variations of voltage on the control grid cause variations of anode current which form, in effect, a magnified replica of the original input (see VALVE). Valves take many forms, but the underlying principle remains the same: the device is a relay in which the only moving parts are electrons.

Methods of using the valve to effect amplification also show some similarity of principle. Consider the case of a valve used to amplify the small signal voltages derived from an aerial circuit and hand them on to a second valve for further amplification; the valve is a voltage-operated device, therefore the input circuits are arranged to apply the maximum voltage to the grid, usually superimposed on the working bias (see GRID BIAS).

It is in the handing-on process that interesting variations appear; here some device is required having a high impedance at the frequencies which are to be amplified. When the incoming signals cause the anode current to vary, a fluctuating voltage is naturally set up across the impedance, and this voltage can be passed on to the grid of the next valve.

The simplest impedance one can use is obviously a suitable amount of resistance, and this method of coupling successive valves is often found in amplifiers intended to work on suitable frequencies. The anode current, in passing through the resistor, produces a drop in the anode voltage, and this drop will vary with changes in anode current; the variations can be passed to the grid of a second valve, and so the signal is handed forward to be amplified still further. Fig. 24 illustrates the essential

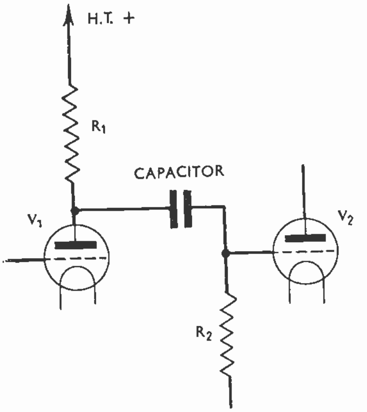


Fig. 24. Essentials of a resistance-capacitance-coupled amplifier. Signal voltages set up across R_1 by variations of anode current are passed through the capacitor to the grid of V_2; R_2 is a grid leak having a very high value.

parts of a resistance-coupled amplifying stage, and there it will be seen that a capacitor is interposed in the wire which carries the signal voltages from the anode of V_1 to the grid of V_2. Its purpose is to block the high positive anode voltage of V_1 and prevent it from reaching the grid of V_2.

This it does effectively so long as its insulation is high, but the varying voltages due to the signals make their effect felt through it, since they are equivalent to an alternating current. Resistor R_1 is the anode load of V_1; R_2 is the grid leak, which permits a suitable bias voltage to reach the grid of V_2.

Resistance coupling is effective at those frequencies for which it is suited, but in dealing with frequencies in the radio range it suffers from a serious weakness; the degree of amplification is reduced by the shunting effect of sundry parallel capacitances, and the higher the frequency the worse the result (see RESISTANCE-CAPACITANCE COUPLING).

For the amplification of signals at radio frequency, therefore, some more effective form of coupling impedance is usual. A tuned circuit is the obvious choice, because it will provide not only a high impedance to the resonant frequency, but will also add to the general selectivity of the receiver by virtue of the resonance effect. The simplest way to use a tuned circuit for intervalve coupling is shown in Fig. 25, where the inductor and capacitor form the conventional tuned-anode coupling to hand the magnified signal on from the anode circuit of V_1 to the grid of V_2.

It will be observed that this circuit shows screen-grid valves: with triodes it would be unstable and would probably oscillate continuously as a result of the feedback effects through the anode-grid capacitances in the valves (see FEEDBACK, SCREEN GRID, VALVE).

The simple tuned anode is not often used in practical receiver designs, because certain benefits, notably in selectivity, can be obtained by loosening the coupling a little. This is usually done by replacing the tuned-anode circuit with a radio-frequency transformer, generally with only its secondary tuned by a variable capacitor. In this way the high-tension voltage is

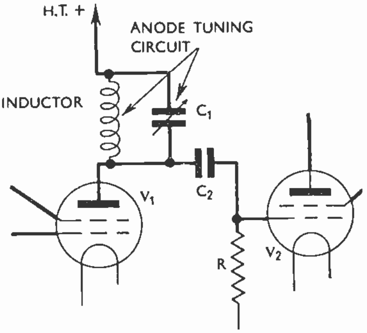


Fig. 25. Tuned-anode R.F. amplifying stage; inductor and variable capacitor C_1 provide the tuned circuit. R.F. voltages set up across it are passed to the grid of V_2 through a blocking capacitor C_2. The grid leak R permits a steady bias voltage to be applied to V_2.

kept off the variable capacitor, with obvious practical advantages, and there is no longer any need for a blocking capacitor in the grid lead of the second valve. Fig. 26 illustrates an elementary form of tuned transformer coupling.

Where the amplifying stage is to work at radio frequency, and must therefore be tunable over a range of wavelengths, it is usual to tune only the secondary. In the I.F. amplifying circuits of a superheterodyne receiver, where only a narrow frequency band is handled, both primary and secondary can be tuned, usually with adjustable, rather then variable, capacitors. It then becomes practical to loosen still further the coupling between primary and secondary, to adjust it for band-pass effects, or otherwise exploit its possibilities for increased selectivity and/or improved fidelity of reproduction.

These are the principal methods of radio- and intermediate-frequency amplification now used. They are comparatively simple, because valves of the screen-grid and R.F. pentode types have substantially solved the problem of stability; when the triode was the only valve available for radio-frequency amplification, many and varied arrangements were devised to achieve stability—bridge circuits, neutrodynes, and the like. These are now used only in high-power senders (see NEUTRALIZATION).

Amplification of frequencies in the audio range calls for different methods. Resonance effects are, in general, undesirable in audio work, where the object is usually to obtain uniform gain at all frequencies within a wide range. An exception occurs in certain communications receivers which use note tuning; they have audio-frequency circuits which resonate at the frequency of the signal note and help to separate it from any jamming signals which may be present.

Resistance coupling has obvious advantages when the object is uniform gain over a wide frequency range, and is much used in modern receivers. With suitable component values, there is little difficulty in obtaining practically uniform amplification of audio frequencies from, say, 25 to 10,000 c/s, an ample range for the highest fidelity of reproduction.

When valves were less efficient and R.F. and I.F. amplification more difficult, it was usual to see transformers used for audio-frequency intervalve coupling. A well-designed transformer will provide uniform gain over a range of audio frequencies sufficiently wide to ensure quite good reproduction, and it will increase the stage gain by approximately the step-up ratio of its primary and secondary windings. Thus, if a valve having an amplification factor of 20 is coupled to the succeeding one with a transformer of 1 : 3 ratio, the stage gain will approach 60; whereas with resistance coupling it can only approach 20 (see AMPLIFICATION FACTOR).

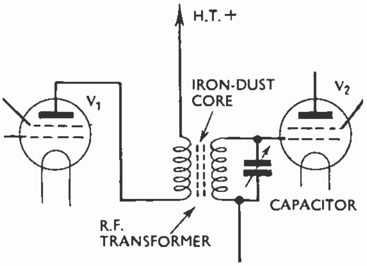


Fig. 26. Essentials of an R.F. amplifying stage with tuned-transformer intervalve coupling. The variable capacitor tunes the secondary of the transformer.

The transformer, therefore, seems attractive, but nevertheless it has become a rarity, partly because it is expensive and has certain practical drawbacks, but perhaps chiefly because designers tend to prefer that a greater part of the amplification shall be done at R.F. and I.F., and less at A.F.

Some of the most difficult amplification problems are met in the vision-frequency circuits of a television receiver. Here the range of frequencies to be amplified with reasonable uniformity runs from an extremely low bottom limit—theoretically zero, but say 20 c/s—to a very high top limit of the order of 2 Mc/s. Resistance coupling of carefully chosen values is the inevitable choice for such work. See AMPLIFIER, BALANCED VALVE-OPERATION, CLASS-A VALVE OPERATION, PHASE SPLITTING, POWER AMPLIFIER, VISION-FREQUENCY AMPLIFIER, VOLTAGE AMPLIFIER.

AMPLIFICATION FACTOR. Figure which indicates the magnifying power of a valve. The factor concerns the relation between a given change of grid voltage and the resultant change of anode current. More precisely, the amplification factor is the ratio between a given change of grid voltage and the change of anode voltage necessary to produce the same change of anode current.

Suppose, for instance, that it is found that a change of one volt on the grid alters the anode current by 2·5 mA, and that to produce the same change of current it would be necessary to vary the anode voltage by 25 volts; the valve would then be said to have an amplification factor of 25, since that is the ratio between the changes of grid and anode voltage which produce the same change of anode current (Fig. 27). Hence the full term is "voltage-amplification factor."

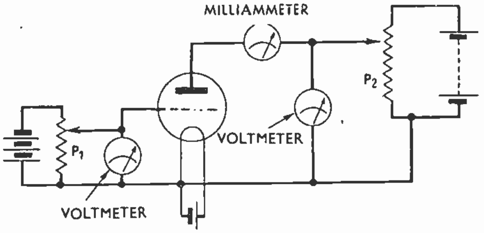


Fig. 27. Simple method of measuring the amplification factor of a battery-operated triode by finding the variations of grid and anode voltage which produce the same alteration of anode current; P_1 and P_2 are potential dividers.

The amplification factor of a valve may be measured as shown in Fig. 28; the grid is given a certain bias and the anode current is noted. A small positive or negative change in grid voltage is made, and the anode current increases or decreases. If the grid potential is reduced by ΔE_g volts, the anode current will increase by ΔI mA.

Now suppose the anode voltage is decreased so as to restore the anode current to its original value; if the necessary change in anode voltage is ΔE_a volts, the amplification factor is then $\frac{\Delta E_a}{\Delta E_g}$. The amplification factor is usually written as μ, mutual conductance as g_m and anode slope-resistance as r_a. It can be proved that $\mu = g_m r_a$.

As to the use of the factor, it may be regarded as a theoretical rating which indicates the maximum amplification obtainable from a particular valve, assuming that there is no voltage magnification inherent in the inter-valve coupling device—as there may be if the coupling is, say, a transformer of some kind. With simple, non-magnifying couplings, such as those of the resistance-capacitance type, the amplification factor of the valve represents the theoretical maximum gain to be had from the stage, a maximum which in practice may be approached but cannot be exceeded. In fact, the stage gain in such a case is given by the expression $G = \frac{\mu R_o}{R_o + r_a}$, where G is the voltage amplification of the stage; μ the amplification factor of the valve; R_o the value of the coupling resistor, and r_a the internal resistance of the valve.

In practice the stage gain of a valve

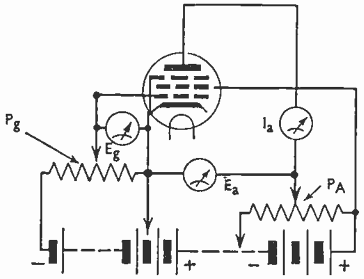


Fig. 28. Measuring the amplification factor of an indirectly heated pentode; the method is as in Fig. 27, using potential dividers P_A and P_g. If ΔE_a is the change in anode voltage and ΔE_g the change in grid voltage, $\mu = \Delta E_a / \Delta E_g$.

is always less than its amplification factor. The discrepancy is greater in pentode or tetrode valves than in triodes. See ANODE SLOPE-RESISTANCE, MUTUAL CONDUCTANCE, STAGE GAIN, TRANSCONDUCTANCE, VALVE CHARACTERISTIC.

AMPLIFIED A.G.C. Form of automatic gain-control wherein the original small control voltages are amplified before application to the valve or valves whose gain is to be controlled in accordance with the strength of the incoming signal. It may be desirable, for example, when the number of controllable valves is small; hence larger control voltages may be needed to produce adequate A.G.C. effects. See AUTOMATIC GAIN-CONTROL.

AMPLIFIED A.V.C. Synonym for AMPLIFIED A.G.C.

AMPLIFIER. Apparatus, circuit or valve performing the function of amplification. The term may, in fact, refer to a particular section of a receiver, as when one mentions the I.F. amplifier of a superheterodyne receiver; or to a self-contained and separate piece of apparatus such as the amplifier used with a public-address equipment; or to any valve which acts as an amplifier.

The amplifier which is a separate and distinct piece of apparatus is generally one for magnifying audio-frequency signals; circuits for amplifying at intermediate or radio frequencies are normally built-in as a fixed part of a complete receiver, for reasons to be discussed.

The self-contained audio amplifier serves many purposes; in amateur circles it is often made up as a separate unit because, being elaborate in design, it is too bulky to fit comfortably on the main receiver chassis; in some of the bigger and more ambitious commercially-made broadcast receivers, the audio amplifier is again built on a separate chassis, fitted on its own shelf in the cabinet, and generally provided with its own power-supply circuits.

An amplifier of this general type is usually made up on the conventional shallow-tray type of chassis: resistors and small capacitors underneath, transformers, smoothing inductors and valves on top, valve holders being set in holes in the tray. Where only a moderate amount of gain is required, the lay-out and the physical design generally is a comparatively simple matter, as the modern tendency to increase the R.F. and I.F. gain and so reduce the amount of work required from the A.F. circuits has made audio design somewhat easier.

Two stages are usually the maximum number employed; the first stage will, in most instances, give a substantial amount of gain—say, between 15 and 30 times—and will drive an output stage consisting of either a single valve or two or more working in a balanced circuit (see BALANCED VALVE-OPERATION). Whereas the first-stage valve is normally one of small power-handling capacity but high voltage-amplification factor, the output valve or valves will be of different type giving comparatively low amplification factor but large power-handling ability.

In any reasonably efficient radio receiving circuit, an audio amplifier of two stages will provide sufficient gain; but in many practical designs

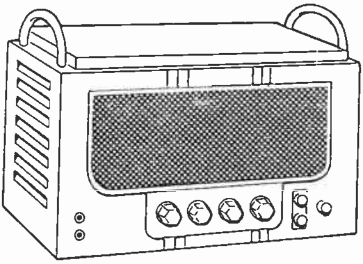


Fig. 29. For public-address work the audio amplifier is usually made up as a self-contained unit in a metal case having ample ventilation.

there are one or more additional valves. These seldom provide additional gain, but merely perform special functions such as contrast expansion, phase splitting, tone control, and the like. In receivers with high-gain R.F. and/or I.F. amplifiers, however, only a single A.F. stage is common.

A third stage of amplification is sometimes provided when only a small input voltage is available, as when the amplifier operates from a gramophone pick-up or microphone of low output. Design is then no longer quite so simple; greater care is necessary to ensure both stability and freedom from mains hum, by adequate smoothing and decoupling of supply circuits, proper lay-out, and attention to such details as arrangement of the wiring.

A well-designed audio-frequency amplifier, an example of which is shown at Fig. 29, is a reasonably stable piece of apparatus, and will tolerate external input and output leads of considerable length; it can be placed at some little distance from the receiver, microphone or gramophone pick-up which is the source of signals; and the loudspeaker can be some way from the amplifier, except that with a three-stage or other high-gain amplifier it may be advisable, even necessary, to use screened cables for these leads.

Amplifiers for radio and intermediate frequencies are quite different; naturally more sensitive to feedback through stray capacitances, they will almost always become unstable if any attempt is made to use them with long input and output leads unless those leads are run in correctly earthed metal sheathing; and unless this is done properly, by treating the connexions as transmission lines and giving due heed to impedance matching at either end, severe attenuation may result. Thus R.F. and I.F. amplifiers are most often found in the form of integral sections of a receiver, where it is easy to ensure stable operation by proper screening, lay-out and decoupling.

In both R.F. and I.F. amplifiers, the modern practice is to use valves with high amplification factors and some form of inter-electrode screening: examples are the screen-grid and the R.F. pentode. Such valves, with their freedom from internal feedback, allow the design of an amplifier which has high gain yet complete stability if proper attention is paid to decoupling and screening.

In some instances, where extremely high gain is the object, each stage of the amplifier may be enclosed in its own screening compartment and the inductors will be individually "canned" as well; for more usual amounts of gain, it is enough to enclose the valves and inductors in individual screening cans, and to separate anode and grid wires by running them on opposite sides of any convenient, earthed, metal object, such as the chassis, an inductor can or the body of a tuning capacitor.

This simplification of construction owes much to the reduction in size of components which has taken place in recent years. The use of iron-dust cores has enabled inductors to be made smaller, as well as more efficient, with a corresponding reduction in the size of their screening cans; similarly, tuning capacitors have shrunk as a result of the smaller plate spacings permitted by more precise methods of assembly. Fixed capacitors have also become smaller as the electrolytic principle has been applied more generally.

Smaller components make possible a less straggling lay-out and enable a skilful designer to produce an inherently stable amplifier with less use of screening; in many modern sets of quite high sensitivity, the only screening is that provided by individual component cans and by the metal chassis.

Compartment screening is perhaps more often seen in special amplifiers for the higher frequencies—above about 5 Mc/s. On such frequencies the individual screening of inductors is frowned upon by many designers and, indeed, on the highest frequencies it is scarcely practicable at all. The usual practice, therefore, is to enclose each stage in its own box, but to leave the inductors open inside that box. See AMPLIFICATION, AMPLIFICATION FACTOR, TETRODE.

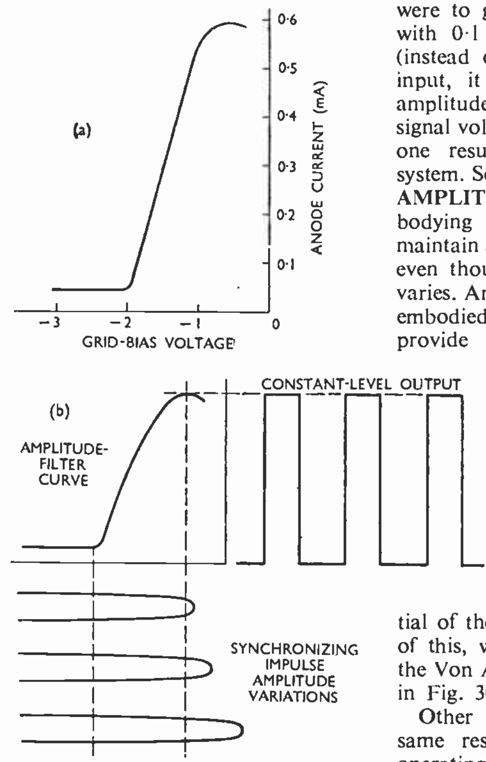


Fig. 30. Effect of amplitude filter on the output of a tetrode: (*a*) grid-volts/anode-current characteristic when screen voltage is higher than anode voltage; (*b*) levelling effect obtained.

AMPLIFIER NOISE. See SET NOISE.

AMPLITUDE. As a noun, synonym for PEAK VALUE.

AMPLITUDE DISTORTION. Variation in the ratio of output to input of a system as the input amplitude is varied. For example, if an amplifier were to give an output of 100 volts with 0·1 volt input, and 180 volts (instead of 200 volts) with 0·2 volt input, it would be said to exhibit amplitude distortion over this range of signal voltage. Amplitude distortion is one result of non-linearity in the system. See NON-LINEAR DISTORTION.

AMPLITUDE FILTER. Device embodying a tetrode or pentode to maintain an output of constant voltage even though the voltage of its input varies. Amplitude filters are frequently embodied in television circuits to provide synchronizing impulses of constant voltage.

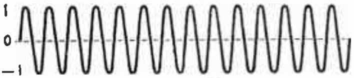
In the original form, the valve is operated so that its grid is always at a negative potential in relation to the cathode. This is achieved because the screen-grid voltage is automatically adjusted in accordance with reductions of the negative potential of the control grid. The principle of this, which is generally known as the Von Ardenne system, is illustrated in Fig. 30.

Other methods of achieving the same result are used, such as so operating the valve that, when its negative grid voltage is reduced beyond a certain point, a comparatively large reduction of anode current results. See LIMITER.

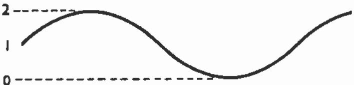
AMPLITUDE MODULATION. Modulation in which the amplitude of the carrier wave is varied by the modulating wave (see MODULATION). Amplitude modulation of a carrier wave is shown in Figs. 31 and 32. In Fig. 31 the modulating factor is unity; in Fig. 32 it is 0·6 (see MODULATION FACTOR). Received signals are stronger as the modulation factor is greater (see MODULATION DEPTH). The modulation envelope shows greater changes as the modulation factor is increased, and it is the variation of the modulation envelope which causes the amplitude of the received signals to vary (see DETECTION, MODULATION ENVELOPE).

The amplitude modulation of a carrier wave by a sinusoidal modulating wave can be considered to be due to adding other sinusoidal waves to the carrier wave. These added waves are called SIDEBAND WAVES (q.v.) and have frequencies which are different from the carrier wave.

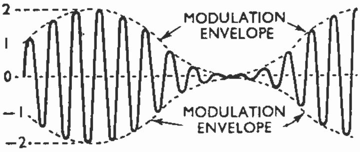
If f_c is the frequency of the carrier wave, then the frequencies of the sideband waves are $f_c + f_m$ and $f_c - f_m$, where f_m is the frequency at which the carrier wave rises and falls; that is, the frequency of the modulating wave.



UNMODULATED CARRIER WAVE
(a)



MODULATING WAVE
(b)



AMPLITUDE-MODULATED WAVE
(c)

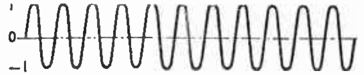
Fig. 31. Diagram showing the wave form produced (*c*) when a steady carrier wave (*a*) is amplitude-modulated by (*b*). The modulation factor is 1.

The amplitude of the sideband waves is determined by the depth of modulation (see MODULATION DEPTH); for a modulation factor of unity each sideband wave has half the amplitude of the carrier wave. Since power depends upon the square of a voltage, and hence on the square of the amplitude of the resultant vector, the peak power in a fully modulated wave (modulation factor = 1) is divided so that $\frac{2}{3}$ of it is contained in the constant-amplitude carrier wave and $\frac{1}{3}$ in the sideband waves.

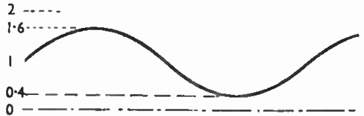
Thus an amplitude-modulated wave is composed of a carrier wave which is of constant amplitude and two sideband waves. The difference between the frequency of the carrier wave and one or other sideband wave is equal to the frequency of the modulating wave, and the carrier-wave frequency is hence the mean of the frequencies of the sideband waves. The difference between the frequencies of the sideband waves is twice the modulating-wave frequency.

The amplitude of the sideband waves determines the modulation depth of the carrier wave; and for sinusoidal modulation the modulation factor is $2S/C$, where C is the carrier wave and S the sideband-wave amplitude.

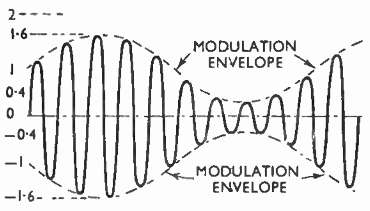
The power of a carrier wave that is amplitude-modulated to a depth of 100 per cent by a sinusoidal wave is 1·5 times that of the unmodulated carrier wave. See AMPLITUDE MODULATOR, ANODE MODULATOR, CARRIER WAVE, COMMUTATION MODULATION, FREQUENCY-CHANGING, LINEAR MODULATION, MODULATED WAVE, MODULATING WAVE, MODULATION, MODULATION FACTOR, NON-LINEAR MODULATION, SINGLE-SIDEBAND MODULATION. SUPPRESSED-CARRIER MODULATION.



UNMODULATED CARRIER WAVE
(a)



MODULATING WAVE
(b)



AMPLITUDE—MODULATED WAVE
(c)

Fig. 32. Wave-form diagram in all respects similar to Fig. 31 except that here modulation depth is less. This diagram is drawn to a modulation factor of 0·6.

AMPLITUDE MODULATOR. Modulator designed to cause a carrier wave to be varied in amplitude in accordance with the amplitude of a modulating wave. See ANODE MODULATOR, LINEAR MODULATION, NON-LINEAR MODULATION.

AMPLITUDE RESONANCE. Term used to distinguish a voltage from a current resonance; but as, in both cases, the amplitude of a quantity is increased at resonance, the term is of little value. See RESONANCE.

ANGLE OF CURRENT FLOW. Fraction of a cycle of an alternating voltage, applied to the grid of a valve, during which there is a flow of anode current. This fraction is expressed in degrees according to the usual convention by which a complete cycle is regarded as consisting of 360 deg. In a class-A amplifier, the angle of current flow is 360 deg., because anode current flows throughout the entire cycle; in more heavily biased valves, anode current may be suppressed during a considerable part of the negative half-cycle of the input voltage. See CLASS-A, CLASS-B, CLASS-C VALVE OPERATION.

ANGLE OF ELEVATION. Angle formed by the ionospheric ray emanating from a sending aerial, and the earth's surface. If the angle of elevation were 90 deg., then the ionospheric ray would be radiated vertically upwards into the ionosphere. See IONOSPHERIC REFRACTION.

ANGLE OF INCIDENCE. Angle formed by the incident ionospheric ray and a perpendicular drawn from the earth's surface upwards through the ionosphere. See IONOSPHERIC REFRACTION.

ANGLE OF POLARIZATION. Angle between the plane of polarization and vertical plane containing the direction of propagation. See PLANE-POLARIZED WAVE, POLARIZATION.

ANGULAR FREQUENCY. Periodicity of an alternating current, or other repetitive phenomenon, in terms of radians per second. This is equal to 2π times the frequency in cycles per second.

ANGULAR SPACING. Angle which bears the same ratio to 360 deg. as the physical spacing does to one wavelength in a direction-finding system employing spaced aerials. Thus, if the spacing is equal to one-eighth of the

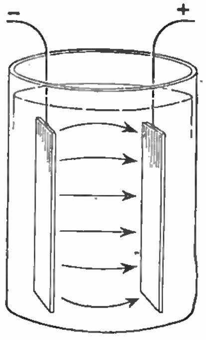


Fig. 33. In an electrolytic cell the negatively charged anions migrate to the positive electrode.

wavelength, the angular spacing is 45 deg.

ANION. Negatively charged particle which moves towards the positive electrode in an electrolytic cell (Fig. 33), or a similar particle in a discharge taking place in a gaseous medium. See IONIZATION.

ANODE. Electrode of a tube or valve which is held at a positive potential with respect to the cathode, and is the principal collector of electrons. Unlike a grid electrode, the anode is usually of solid construction and electrons do not pass through it. The anode is usually the electrode which is farthest from the cathode, and it generally encloses the grid electrodes. In some screen-grid valves, however, the screen grid is located on both sides of the anode. Although there are exceptions to these generalizations, the anode is distinguished by one or another of the characteristics set out above.

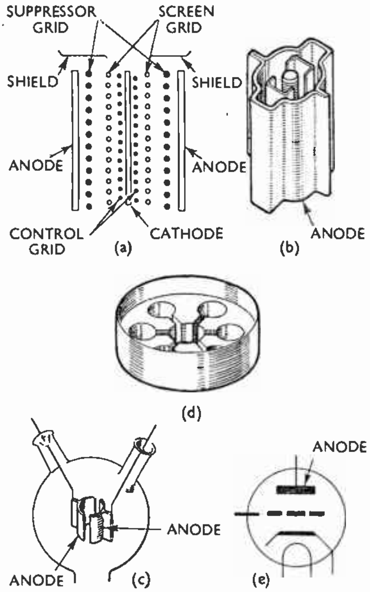


Fig. 34. The anode in various forms of valve: (*a*) diagrammatic section through a pentode; (*b*) the anode structure of a beam tetrode, (*c*) a split-anode magnetron, (*d*) a multi-cavity magnetron; and (*e*) representation distinguishing the anode in an indirectly-heated triode.

In a glow-tube, either electrode can be made positive and so be properly called the anode, but usually the electrodes are of different shape, and the tube functions better when one of the electrodes is made positive with respect to the other. In a cathode-ray tube, the electrode which controls the axial velocity of the electrons is sometimes called an anode; its proper description is an accelerator.

Fig. 34 distinguishes the anode electrode from others in different types of valve. See AIR-COOLED ANODE, ANODE CURRENT, ANODE DISSIPATION, ANODE-FEED CURRENT, ANODE IMPEDANCE, ANODE SLOPE-RESISTANCE, WATER-COOLED VALVE.

ANODE A.C. CONDUCTANCE. See ANODE SLOPE-CONDUCTANCE.

ANODE A.C. RESISTANCE. See ANODE SLOPE-RESISTANCE.

ANODE BATTERY. Synonym for HIGH-TENSION BATTERY.

ANODE BEND. Curved portion at the bottom of the anode-current/grid-voltage characteristic of a valve (see CHARACTERISTIC CURVE). With a valve operated at a given anode voltage, a sufficient negative voltage on the grid prevents anode current from flowing, the negative field due to the grid being more than sufficient to counteract the positive field due to the anode. As the grid is made less negative, a condition is reached where the two effects balance exactly. Reducing the (negative) grid voltage still further permits anode current to flow.

The relationship between anode current and grid voltage is of the form shown in Fig. 35. It will be seen that the current increases slowly at first, and then more rapidly, finally settling down to a straight-line, or linear, condition in which current and voltage are linearly related. The first part of the characteristic is called the anode bend, or bottom bend, while the latter part is referred to as the linear portion.

ANODE-BEND DETECTION. Detection of a radio signal by means of a valve operating over the curved portion of the anode-current/grid-voltage characteristic (see DETECTION). If a valve is operated at a point such as *A* in Fig. 35, making the grid less negative will produce an appreciable increase in anode current; whereas making the grid more negative will produce only a small reduction in the already small anode current.

Hence, if we apply a symmetrical voltage variation to the grid, above and below the chosen mean value, the increase in the anode current on the positive half-cycles will be greater than the decrease on the negative half-cycles. Consequently, the mean anode current will increase. Thus, although the signal variations may be occurring too rapidly to be detected by certain methods, their presence will be indicated by the change in anode current which has resulted.

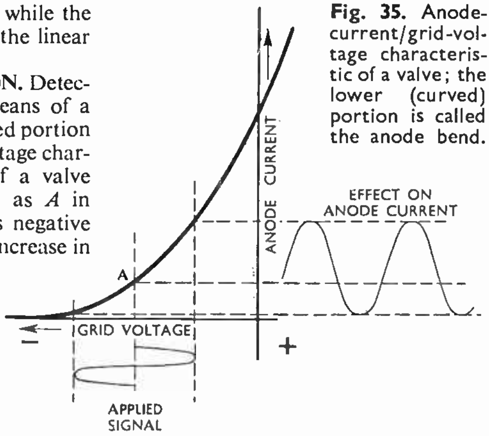


Fig. 35. Anode-current/grid-voltage characteristic of a valve; the lower (curved) portion is called the anode bend.

ANODE-BEND RECTIFICATION. Rectification produced by the curvature of the anode-current/grid-voltage characteristic. See ANODE-BEND DETECTION.

ANODE CIRCUIT. Circuit which offers an impedance to the valve anode when the valve is considered as a generator of alternating current. The anode circuit also conducts current from the high-tension source to the anode, and forms part of the anode load. Fig. 36 shows a valve amplifier and distinguishes, by bold lines, what is usually spoken of as the anode circuit. See ANODE LOAD, ANODE-FEED CURRENT.

ANODE CONDUCTANCE. See ANODE SLOPE-CONDUCTANCE.

ANODE CONVERTER. Any converter which gives a D.C. voltage for application to the anode of a valve.

ANODE CURRENT. Current flowing to and from an anode electrode such as that in a valve or vacuum tube. See ANODE-FEED CURRENT.

ANODE D.C. CONDUCTANCE. Reciprocal of anode D.C. resistance.

ANODE D.C. RESISTANCE. Anode voltage divided by the anode current (Fig. 37). The anode D.C. resistance of a valve is not important in most circumstances; the important resistance as regards an electrode, be it anode, screen-grid or control-grid (when grid current flows), is the slope resistance. See SLOPE RESISTANCE.

ANODE DISSIPATION. Term denoting the dissipation of heat by the anode. Electrons travelling at high velocity strike the solid anode and

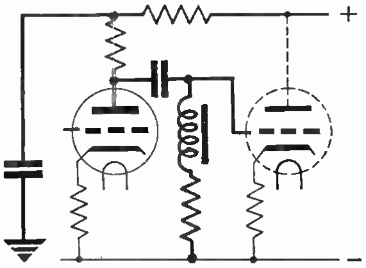


Fig. 36. In this triode-amplifier diagram the anode circuit is distinguished by the use of heavy lines.

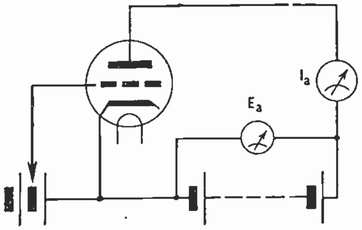


Fig. 37. To find the anode D.C. resistance of the valve, anode-voltage E_a is divided by anode-feed current I_a. The p.d. across the instrument measuring I_a is assumed to be negligible.

generate heat (see ELECTRON VELOCITY). The dissipation is proportional to the anode-feed current, as read by a moving-coil ammeter or milliammeter, multiplied by the anode volts as read by a voltmeter.

When the valve has to handle considerable power, special precautions have to be taken to dissipate the heat generated at the anode, otherwise it would melt. For valves handling powers up to 100 W, the anode is a cylinder of metal and no special cooling measures are necessary. For handling powers which are measurable in kilowatts, the bulb may be made of silica glass and a jet of air blown upon the surface of the bulb. For higher powers, the anode electrode is not enclosed in the bulb and external means are used to cool it. In one arrangement, air is blown upon fins attached to the anode: in another, water circulates over the anode surface. See AIR-COOLED ANODE, COOLED VALVE, RATED ELECTRODE DISSIPATION, WATER-COOLED VALVE.

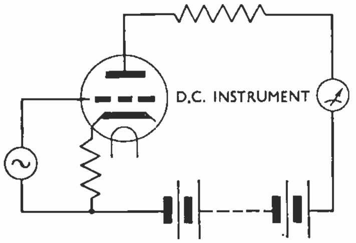


Fig. 38. An instrument which records only the D.C. component of current flowing to and from the valve anode reads the anode-feed current.

ANODE DROP. Synonym for VOLTAGE DROP in an anode circuit.

ANODE-FEED CURRENT. D.C. component of the current flowing to and from the anode electrode. When a valve is used as an amplifier, the current flowing to and from the anode electrode is made up partly of a direct, and partly of an alternating, current. The anode current is the total current, however made up; the anode-feed current is the D.C. component of the total current; and the anode-load current is the A.C. component of the total current (Fig. 38). See ANODE CURRENT.

ANODE-FEED RESISTANCE. Resistance of the anode-feed resistor.

ANODE-FEED RESISTOR. Resistor, shunted by a capacitor which forms the circuit to decouple the anode circuit from the high-tension source. Fig. 39 shows the anode-feed resistor in a resistance-capacitance-coupled amplifying valve.

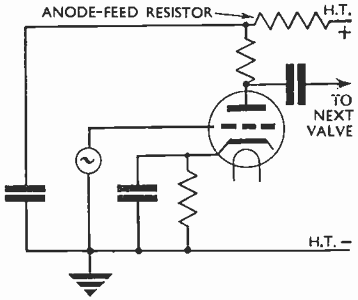


Fig. 39. Typical decoupling circuit showing use of an anode-feed resistor.

ANODE IMPEDANCE. Internal impedance between the anode and cathode of a valve, considered as a generator of A.C. See ELECTRODE IMPEDANCE.

ANODE LOAD. Circuit mainly responsible for the anode-cathode impedance of a valve and in which the major part of the power or volt-amperes is delivered by the valve anode when this is considered as a source of power. Fig. 40 shows a valve connected as an amplifier; it is clear that the alternating voltage developed at the anode will produce alternating current in all the circuits which branch from the anode, including the conductive circuit in which the anode-feed current flows.

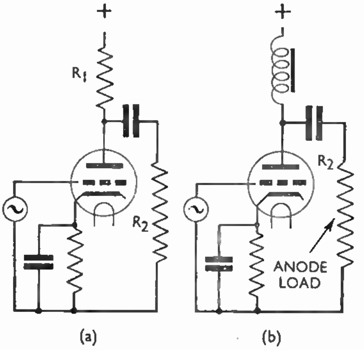


Fig. 40. Anode load of the voltage amplifier (*a*) is, strictly, R_1 and R_2 in parallel, but in the assumed power amplifier (*b*) it is properly R_2.

In diagram (a), if R_2 is equal to or greater than R_1 (as it might be in a resistance-capacitance amplifier) the anode load is strictly R_1 and R_2 in parallel; but the power dissipation in R_1 and R_2 would be small, as the valve is a voltage rather than a power amplifier. In Fig. 40b the load is R_2; its value is usually of the order of the anode slope-resistance of the triode, whereas the impedance of the choke is very much greater. Very little power is delivered to the inductor carrying the anode-feed current because its resistance is usually very small. See ANODE CIRCUIT, ANODE CURRENT, ANODE-FEED CURRENT.

ANODE MODULATOR. Amplitude modulator using valves. The anode voltage of a class-C amplifier, which amplifies the carrier wave, is varied in accordance with the amplitude of the modulating wave. The carrier-wave output from the class-C amplifier varies in accordance with its anode voltage, and hence in accordance with the variations of the modulating wave. The diagrams of Fig. 41 show forms of anode modulator. The so-called modulated amplifier is adjusted so that the carrier-wave output is substantially proportional to the anode voltage.

This anode voltage, as seen from the diagrams, is determined by the output from the modulating-wave amplifier. In order that the carrier-wave output from the modulated amplifier may be doubled or reduced to zero (100 per cent modulation, see MODULATION FACTOR) it is necessary for anode voltage to swing between twice a mean value and zero. If both the modulated

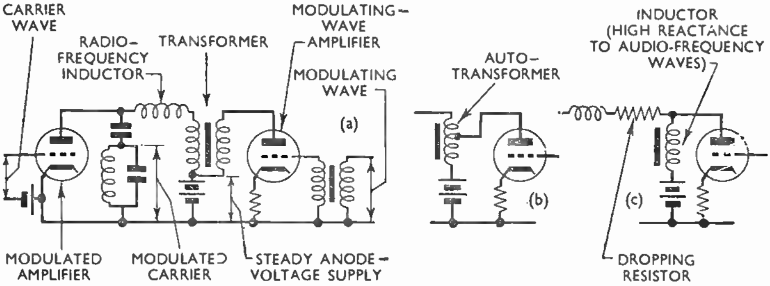


Fig. 41. Anode-modulator circuits (*a*), (*b*) and (*c*) differ only in the method by which the modulating-wave voltage is added to the steady anode voltage.

and modulating-wave amplifiers were energized by the same value of high-tension voltage, the voltage from the modulating-wave amplifier would also have to swing between zero and twice a mean value.

This condition is impossible to attain without introducing severe distortion (see AMPLIFIER). Thus arrangements must be made to ensure that the steady anode voltage of the class-C, or modulated, amplifier is considerably less than that supplied to the modulating-wave amplifier.

The arrangements shown in Fig. 41—a transformer in (a), an auto-transformer in (b) and a dropping resistance in (c)—ensure this condition. Fig. 42 shows a more detailed diagram; the separator valve is necessary to ensure that the output from the modulated amplifier is of constant frequency, because an oscillator, when anode-modulated, slightly varies its frequency. See AMPLITUDE MODULATION, AMPLITUDE MODULATOR.

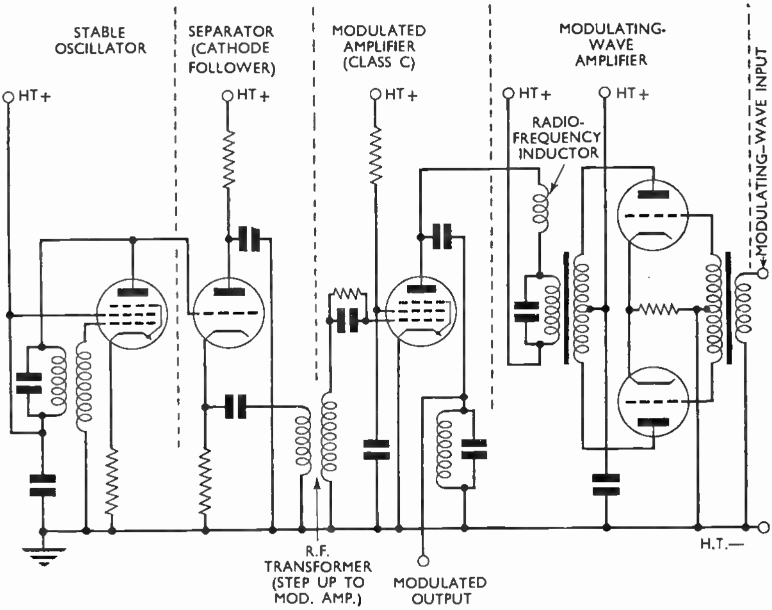


Fig. 42. Schematic diagram of a low-power anode modulator comprising four stages: stable oscillator, cathode follower, an R.F. amplifier and an A.F. amplifier.

ANODE RECTIFICATION. Any rectifying action which arises from a non-linear relationship between anode current and applied voltage. The term is usually employed in the same sense as anode-bend rectification.

It should be noted, however, that there is another way in which anode rectification can arise. This is due to conditions where another curvature of the anode-current characteristic occurs as, for example, that shown in Fig. 43. Such a condition can arise in a valve in which the emission is limited by saturation or deliberate restriction as, for instance, in the case of a tetrode or pentode with low screen voltage.

Clearly, under such conditions, a similar process to anode-bend detection can take place, the difference being that the positive grid swings produce little change of anode current, while negative swings produce an appreciable reduction, the asymmetrical action resulting in rectification.

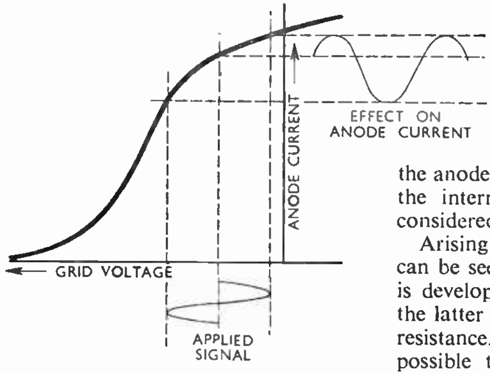


Fig. 43. Characteristic of a tetrode or pentode in which emission is limited, providing conditions in which anode rectification will take place.

ANODE RESISTANCE. Synonym for ANODE SLOPE-RESISTANCE.

ANODE SLOPE-CONDUCTANCE. Reciprocal of ANODE SLOPE-RESISTANCE.

ANODE SLOPE-RESISTANCE. Slope resistance is the ratio of a small path of a valve (see SLOPE RESISTANCE). Slope resistance is the ratio of a small voltage change to the resulting current change produced in any non-linear conductor. Thus anode slope-resistance is the reciprocal of the slope of the anode-volts/anode-current characteristic of a valve in terms of anode-voltage change/anode-current change.

Considered as a generator of power, the valve, like any other electrical generator, can be regarded as an e.m.f. in series with an impedance; the impedance is often, and may be here considered as, a resistance (Fig. 44). Thus the anode slope-resistance of a valve is the internal resistance of the valve considered as a generator of power.

Arising out of this conception, it can be seen that the maximum power is developed in the anode load when the latter is equal to the anode slope-resistance. It may not always be possible to match these resistances; in the case of a pentode, it is impossible, and the maximum power with minimum distortion may not be obtainable. By using negative feedback with pentode valves, or by using triodes, the resistance match can be made and the maximum power thus delivered to the load.

A pentode has a very high anode slope-resistance, sometimes of the order of megohms, but the load cannot be matched to so high a resistance and smaller loads must be used. Thus the pentode is equivalent to a constant-current generator.

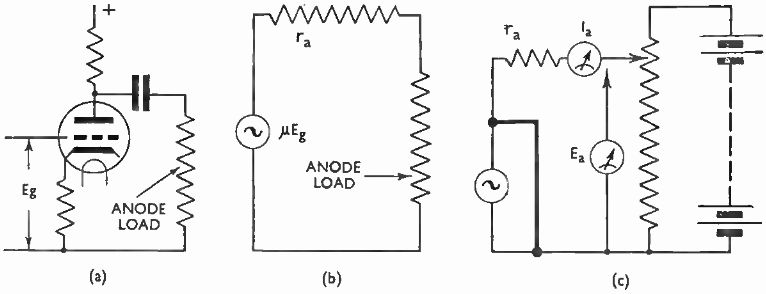


Fig. 44. Typical valve amplifier circuit (*a*); in the electrical equivalent (*b*) the valve is substituted by a generator of e.m.f. μE_g. In (*c*) is shown the method of measuring, with the e.m.f. short-circuited, the slope resistance r_a as $\Delta E_a/\Delta I_a$.

A typical power triode has a slope resistance which can easily be matched to the load; the anode slope-resistance is $r_a = \frac{\Delta E_a}{\Delta I_a}$, where ΔE_a is a small change of anode voltage, and ΔI_a the resulting small change of anode current; the mutual conductance is $g_m = \frac{\Delta I_a}{\Delta E_g}$, where ΔE_g is a small change of grid voltage and I_a the resulting change of current. Therefore, $r_a g_m = \frac{\Delta E_a}{\Delta I_a} \times \frac{\Delta I_a}{\Delta E_g} = \frac{\Delta E_a}{\Delta E_g}$; but the amplification factor $\mu = \frac{\Delta E_a}{\Delta E_g}$; thus we arrive at the important conclusion that $\mu = g_m r_a$. This expression relates the three fundamental characteristics of a valve. See AMPLIFICATION FACTOR, MATCHING, MUTUAL CONDUCTANCE, TRANSCONDUCTANCE, VALVE CHARACTERISTIC, VOLTAGE AMPLIFIER.

ANODE STOPPER. See PARASITIC STOPPER.

ANODE TAP. In a tuned-anode circuit, the point on the inductance coil to which the anode is connected so that the valve works into optimum impedance.

ANODE VOLTAGE. Steady component of the voltage between anode and cathode of a valve; or, the alternating component of the anode voltage; or, the steady component plus the alternating component of the anode voltage. The term is sometimes used as being synonymous with "anode potential."

ANODE-VOLTS/ANODE-CURRENT CHARACTERISTIC. Characteristic obtained by plotting anode current against anode volts on a graph. The anode-volts/anode-current characteristic of a valve is useful when designing amplifiers (see HARMONIC DISTORTION, LOAD LINE). Fig. 45 shows a typical set of curves for a triode. The slope of any graph, at any point on it, gives the anode slope-conductance at the given anode volts and anode current. The graphs of valves with a control grid are usually plotted for different fixed values of grid bias. In a pentode the anode-current/anode-volts curve is plotted as described with the screen-grid volts fixed. A different set of graphs for the pentode are obtained for different fixed values of screen-grid volts. See GRID-VOLTS/ANODE-CURRENT CHARACTERISTIC, VALVE CHARACTERISTIC.

ANOMALOUS DISPLACEMENT CURRENT. Current in a circuit containing a capacitor with imperfect dielectric. It is additional to the normal leakage current, and continues to flow after the charging or discharging current has ceased or attained a very low value.

ANOMALOUS PROPAGATION. Freak propagation of very high-frequency radio-waves which appears to coincide with a condition of temperature inversion in the lower atmosphere.

Very high-frequency waves generally obey optical laws in that their range is limited by the horizon; anomalous propagation (sometimes abbreviated to "anoprop") extends the propagation of very high-frequency waves beyond, and sometimes very considerably beyond, the optical range. See CENTIMETRIC WAVE, VERY HIGH-FREQUENCY WAVE.

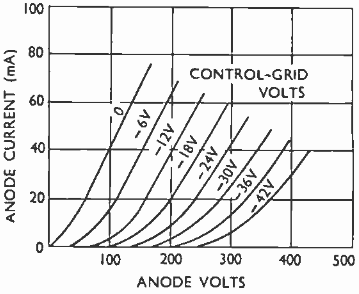


Fig. 45. Typical set of curves representing the anode-volts/anode-current characteristic of a triode.

ANTENNA. Synonym for AERIAL.

ANTENNA EFFECT. Error which results in a direction-finder when a closed aerial, such as a loop, tends to act as an open aerial, the complete assembly being connected to earth through, for instance, the stray capacitances of the associated receiving circuits (Fig. 46). If the paths to earth from either side of the loop circuit are not of equal impedance, a difference of potential is set up *across* the loop circuit, which in turn produces signals in the receiver and obscures or vitiates the direction-finding indications.

In practice, antenna effect is overcome in a number of ways. For example, a balancing capacitor may be used to equalize the impedance to earth from either side of the aerial circuit, or some scheme of centre-point earthing may be used with an inductive coupling from aerial to receiver.

ANTI-INDUCTION NETWORK. Network which may be inserted in two telegraph circuits with the object of reducing crosstalk.

ANTI-INTERFERENCE AERIAL-SYSTEM. Arrangement in which pick-up of energy is confined to the aerial itself, usually by the use of a screened or balanced feeder or down-lead (lead-in). The system is chiefly beneficial in reducing man-made interference originating at or near ground level.

ANTI-MICROPHONIC VALVE HOLDER. Valve holder designed to insulate the valve from mechanical vibration. Slight movement of valve electrodes relative to one another causes modulation of the anode current. This is particularly undesirable in the early stages of a multi-stage amplifier (because resultant noise is amplified by later stages) and in any stage of a high-quality amplifier.

ANTINODE. Any point in a system having a non-uniform distribution of current (or voltage) at which the current (or voltage) has maximum r.m.s. value. See NODES AND ANTINODES.

ANTISTATIC AERIAL. See ANTI-INTERFERENCE AERIAL-SYSTEM.

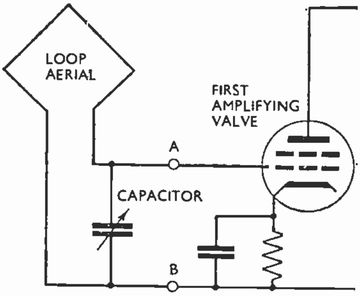


Fig. 46. Antenna effect is produced because capacitances to earth from the two sides (*A* and *B*) of the tuned circuit are unequal, creating voltages across the capacitor which do not respond normally to rotation of the loop.

APERIODIC. Without natural frequency; responding equally to all frequencies. See NATURAL FREQUENCY, RESONANCE.

APERIODIC AERIAL. Aerial working on frequencies other than its resonant frequencies, and sufficiently remote from them to ensure reasonably uniform functioning over its range of operating frequencies. This arrangement, though in many ways less effective than a fully tuned aerial-system, offers substantial advantages when the circuits of a receiver are to be gang-tuned (see GANGING).

It then eliminates a circuit—that of the aerial-earth system—which possesses constants so different from those of the closed circuits of the receiver as to defy ganging by normal methods. This, of course, applies to the open form of aerial. A loop can more readily be ganged with the closed circuits of a receiver.

APERIODIC CIRCUIT. Circuit without frequency discrimination, responding equally to all. The term is commonly applied to circuits which are not truly aperiodic, but whose resonant frequency is outside the range on which they work. They thus function with approximately equal efficiency over that range. See TUNING.

APERTURE DISTORTION. Distortion in television due to the impossibility of using a sufficiently small aperture in the sender of a television system. In the case of mechanical scanning, the aperture is the area illuminated by the moving spot of light which scans the scene. In the case of a storage camera, the effective size of the aperture is the size of the cathode-ray spot which scans the mosaic.

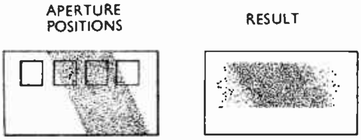


Fig. 47. Scanning of a simple pattern (*left*) results in irregular outlines (*right*) where the aperture "enters" and "leaves" the pattern—an effect known as aperture distortion. The smaller the aperture the sharper the outline produced on the screen.

It will be obvious that it is impossible to transmit details finer than the area represented by the aperture. Fig. 47 shows a simple type of image, consisting of a pattern scanned by a square aperture. As the aperture moves from left to right, the average light intensity of the portion covered by the aperture varies gradually, instead of suddenly, from light to dark and a more or less distorted pattern is the result.

APPARATUS. Assembly of components in which each component performs some definite function. Bridges, potential dividers and signal generators, for instance, are referred to as "measuring apparatus." But the term is variously used, and is often made to appear as synonymous with "equipment" and, notably in U.S.A., with "component." See MEASURING INSTRUMENTS.

APPARENT RESISTANCE. Synonym for IMPEDANCE.

APPLETON LAYER. See F-LAYER, IONOSPHERE.

ARC. Luminous electrical discharge that takes place through ionized gas.

ARC-BACK. Reversal of current flow in the arc of a MERCURY-ARC RECTIFIER (q.v.). In certain conditions electrons pass from the anode to the mercury pool, instead of in the opposite direction. This may be due to overheating of the anode or to condensation of mercury on it. The effect of arc-back is to cause a short-circuit on the H.T. transformer.

ARC CONVERTER. Complete arc assembly in a Poulsen arc generator (see POULSEN ARC). The converter comprises the arc electrodes, an electromagnet on either side of the electrodes for lengthening and stabilizing the arc, and an hydrogenous vapour container; the vapour lowers the temperature of the arc.

ARC GENERATOR. In an arc sender, the discharge across the arc which generates the high-frequency oscillations in the sender circuit.

ARC MODULATION. System of light control in which an ordinary arc light is controlled in intensity by variation of the voltage across it. The system is unsuitable for high-definition television, and is relatively insensitive as it requires considerable power in order to provide light variation.

ARC RECTIFIER. Any electric arc which has a greater conduction when a voltage is applied to it in one sense than in the other. The mercury arc is commonly used as a rectifier in practice. See MERCURY-ARC RECTIFIER.

ARC SENDER. Radio sender in which R.F. oscillations are generated by means of an electric arc. See POULSEN ARC.

ARC TRANSMITTER. Synonym for ARC SENDER.

ARMATURE. Normally, the rotating part of a D.C. motor or generator (see MOTOR). The term is also used sometimes to describe the *stator* of a synchronous generator. In addition, the term is employed to denote the moving part of any electrical device, such as an electric bell or a relay.

ARMSTRONG CIRCUIT. Name sometimes given to the superheterodyne circuit, in recognition of its inventor, Major Edwin Armstrong. See SUPERHETERODYNE RECEPTION.

ARTICULATION. Percentage of speech-sounds correctly received over a radio-communication or reproducing system, or, in reference to acoustics, the percentage that is heard in an auditorium.

ARTIFICIAL AERIAL. Circuit possessing the values of inductance, capacitance and resistance characteristic of a particular type of aerial, but which does not radiate any appreciable fraction of the energy put into it. It is chiefly used in the testing of senders when a radiating aerial might cause interference. It is sometimes known as a dummy aerial.

ARTIFICIAL EARTH. See COUNTERPOISE.

ARTIFICIAL LINE. Electrical network, usually consisting of inductors, capacitors and resistors, the values and arrangement of the components being such as to simulate some or all of the characteristics of a given transmission line.

ARYTHMIC SYSTEM. See START-STOP SYSTEM.

A-SERVICE AREA. Service area in which the field strength is greater than 10 mV/m. See SERVICE AREA.

ASPECT RATIO. Ratio of the breadth to the height of a television picture.

ASTIGMATISM. Inability to focus a beam in all axial planes simultaneously, due to imperfection in the lens. Most cathode-ray tubes suffer more or less from astigmatism, usually in two planes at right-angles. When the focusing control is adjusted to bring the spot to sharpest focus horizontally it is not quite in focus vertically and appears as a short vertical line; and vice versa, as shown in Fig. 48. In a television receiver, it is usually advisable to give preference to horizontal focus, allowing the vertical size of the spot to occupy a complete line width, thereby rendering the line structure least visible. See CATHODE-RAY TUBE, ELECTRON LENS, FOCUSING.

ASYMMETRICAL DEFLECTION. Unequal deflection of the electron beam about a centre line in a CATHODE-RAY TUBE (q.v.). The effect may be due to the application of unequal potentials to opposing deflector plates or coils, or to magnetic effects outside the C.R.T. assembly, especially if the tube is inadequately shielded. The term is perhaps most frequently applied in the case of a C.R.T. of which one deflector plate is maintained at zero or earth potential, while the opposing plate is made positive or negative.

ASYMMETRICAL SIDEBAND MODULATION. System of modulation in which one group of sideband waves is transmitted without attenuation, the other group being attenuated in the outer regions of the sideband. In normal amplitude modulation, the amplitudes of the sideband waves in the upper and lower sidebands are equal, but in asymmetrical sideband modulation, one group of sideband waves suffers increasing attenuation as the frequency of the sideband wave increases or decreases from the sideband carrier-wave frequency.

The object of the scheme is to decrease the effective frequency band

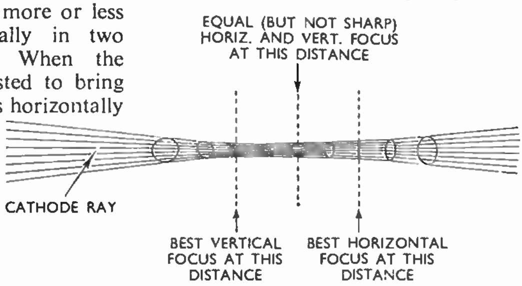


Fig. 48. Diagram showing the cross-sections at various distances along a cathode ray suffering from astigmatism.

occupied in broadcasting programmes from a radio sender. Distortion is inevitably created by attenuating sideband waves in this manner, but this distortion can be made negligible in sending speech and music, because the higher frequencies of the modulating wave have less amplitude than those in the lower. The system has not been put into practice in the broadcasting of sound, but it has application to television senders. See MODULATION DISTORTION.

ASYMMETRICAL SIDEBAND TRANSMISSION. System of radio sending in which one sideband is partly suppressed; this reduces the band width of the transmission and enables more channels to be accommodated within a given frequency band. One method is to employ a single-sideband system of sending, with a reduced carrier amplitude and a residual second sideband. With this system, the band width is reduced to about 60 per cent of that which is occupied by a double-sideband transmission. See ASYMMETRICAL SIDEBAND MODULATION.

ASYNCHRONISM. Reverse of synchronism.

ATMOSPHERIC ARC RECTIFIER. Arc rectifier in which the arc takes place in air at atmospheric pressure. Such a rectifier, however, finds no use in practice.

ATMOSPHERICS. Electromagnetic radiation due to natural causes. It is often called static, especially in America, though that term, if used at all in this connexion, should be reserved for the third of the four classes of natural interference described below. Atmospherics are among the main types of interference and noise, and in some circumstances limit or entirely prevent long-range radio communication, especially on certain frequency bands.

LIGHTNING, which is occurring in some part of the world at practically all times of day or night, is the most important source of atmospherics. The power radiated during a flash is enormously greater than that from any radio station, and its path—which is equivalent to a radiating aerial—is often miles long, and is generally high up, so the conditions for long-range propagation are favourable. Moreover, the transient nature of the discharge means that appreciable radiation occurs at all radio frequencies except, possibly, the very highest. Each flash is heard in the receiver as a crash, which is often prolonged by reflections. The intensity of interference likely to be experienced depends, in a complicated manner, upon time, place and frequency.

When a thunderstorm is taking place within a hundred miles of the receiver, interference is received directly, the greatest intensity being at about 10 kc/s, falling off fairly uniformly with increasing frequency, until it is negligible at ultra-high frequencies unless within a few miles.

Lightning is most prevalent during summer afternoons and evenings over large tropical land areas. In such areas, radio communication at the lower frequencies varies from difficult to impossible. In temperate and arctic latitudes, where local thunderstorms are exceptional, most atmospherics come from whichever tropical area is enjoying a summer afternoon at the time; and the mean intensity depends on the propagation conditions for the frequency of reception.

Low radio-frequency waves are directly propagated to great distances, and atmospherics are received more or less strongly and continuously all over the world. Around one and two megacycles per second they are very weak by day but fairly strong by night because of ionospheric reflection. At 10–20 Mc/s this situation is reversed, and above about 30 Mc/s reception is negligible at all times except during local storms.

Means for reducing interference by atmospherics include restricting the band-width of reception to the minimum necessary for the desired signal, using a directive aerial to exclude atmospherics coming from all directions other than that of the desired station, and making use of circuits to limit amplitude to that required for the desired signal. Frequency modulation is an effective type of transmission for this purpose.

PRECIPITATION. Electrically charged rain, snow, hail, dust or steam can sometimes charge an insulated receiving aerial or adjacent conductor to a sufficiently high potential for it to emit sparks, causing intense click interference. If the aerial is so well insulated that the potential reaches the corona point, a hissing noise results, which may be enough to blot out all except strong signals.

This type of interference, although occasionally troublesome on the ground, is of great concern to aviation. Aircraft are often charged, not only as just described, but by the friction of dry precipitation on the structure. The corona point may be reached in a few seconds, and the resulting discharge may render the radio ineffective under conditions when it is most needed. One remedy is to tow a fine wire or a metallized cotton wick to discharge the aeroplane more quietly at a point remote from the aerial.

STATIC. If an aircraft approaches an intense electromagnetic field, such as that near a thunder cloud, it may reach a sufficient potential for a noisy corona discharge, or static, to take place, as with precipitation. The same phenomenon sometimes occurs at ground stations, causing a hissing sound in contrast to the crashes and rumbles of lightning.

COSMIC NOISE. Sometimes called Jansky noise after the observer who first reported it in 1932, this consists of a weak hissing or rushing not easily distinguished from set noise. From the fact that it appears mainly to come from the Milky Way, the inference is that it must emanate from outer space, and that it is possibly brought about by a sort of cosmic thermal agitation.

Jansky detected the noise at 20 Mc/s but, more recently, Reber has investigated it on 160 Mc/s. At relatively low frequencies it is masked by other types of interference. Although it has little practical bearing on radio, cosmic noise is of great astrophysical interest. See CORONA, INTERFERENCE, NOISE, THERMAL-AGITATION VOLTAGE.

ATOM. Smallest particle of an element capable of entering into a chemical relationship. The atom is postulated as consisting of a heavy nucleus carrying a positive charge of electricity, surrounded by a system of electrons which represent negative charges and by their number decide the chemical properties of the element.

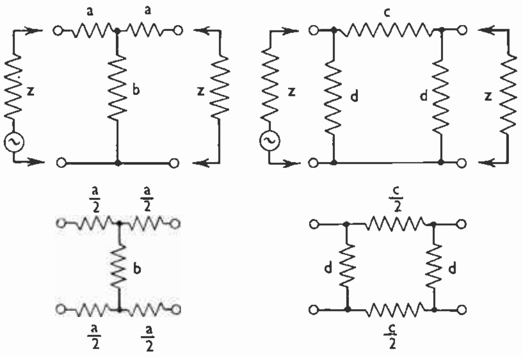
ATTENUATION. Effect due to loss of power in resistive parts of a circuit which reduces the amplitude of a wave or direct current between two points in the circuit. When a wave passes through any network there is likely to be a change of amplitude between two points in the network. If there is a reduction of amplitude due to losses in resistance, the network is said to cause attenuation of the wave.

In general, there are two effects present when a wave passes through a network, one brought about by the effects of resistance, the other by reactance. Attenuation is a term concerned with changes of amplitude due to losses in resistive parts of the circuit. Phase changes also produce alteration of amplitude, but such changes are due to the effects of reactance and there is no loss of power.

In line telephony, the signals at the input to the line are generally of greater amplitude than when they appear at the output terminals of the line; the line is then said to have produced attenuation of the waves representing the signal. In the propagation of radio-waves over the earth's surface, losses in the ground cause the strength of the waves to fall by a greater amount than determined by the inverse-distance law; such waves are attenuated. See ATTENUATION COEFFICIENT.

ATTENUATION COEFFICIENT. Ratio expressing by how much the amplitude of a wave is changed by losses in resistive parts of the circuit, when the wave passes through a transmission channel. Thus the term is descriptive of the real part of the propagation coefficient. The propagation coefficient is a ratio of vector quantities and contains two parts, called real and imaginary; the real part is associated with changes of amplitude due to loss of power in resistance, the imaginary part with effects of reactances causing phase change. Thus the attenuation coefficient is that which concerns loss of power. See PHASE-CHANGE COEFFICIENT, PROPAGATION COEFFICIENT.

ATTENUATION CONSTANT. Synonym for ATTENUATION COEFFICIENT.



ATTENUATION db	$\frac{a}{z}$	$\frac{b}{z}$	$\frac{c}{z}$	$\frac{d}{z}$
1 . .	0·0575	8·667	0·1154	17·39
2 . .	0·1146	4 305	0·2323	8·724
3 . .	0·1710	2·839	0·3523	5·848
4 . .	0·2263	2·097	0·4770	4·420
6 . .	0·3323	1·339	0·7470	3·009
10 . .	0·5195	0·7027	1·423	1·925
15 . .	0·6980	0·3673	2·723	1·432
20 . .	0·8182	0·2020	4·950	1·222
30 . .	0·9387	0·0633	15·80	1·065

Fig. 49. Data for calculating values of elements of a resistive attenuator.

ATTENUATION DISTORTION. Distortion due to variation of loss or gain with frequency. The term is inappropriate and is rarely, if ever, used, the effect being generally known as *frequency* distortion. It is measured by applying to the input of the unit under test a sinusoidal signal, and noting the ratio of r.m.s. value of fundamental output to that of the input, over the band of frequencies concerned; care is taken to avoid or allow for non-linear distortion.

The result is generally expressed as a graph of gain or loss (in decibels) against frequency. Ideally, all amplifiers and other links in a chain of communication should be equally effective at all frequencies within the desired band; but if that is impracticable or uneconomical, the alternative is to impose an equal and opposite distortion by means of a tone control or equalizer. See DISTORTION, EQUALIZER, PRE-EMPHASIS, RESPONSE GRAPH, TONE CONTROL.

ATTENUATION EQUALIZER. Equalizer placed in the output circuit from a line to produce substantially equal amplitudes of waves of different frequency. When a group of waves is passed through a transmission line, it is possible that those of higher frequency are more attenuated than those of lower frequency. In speech transmission over lines, this effect distorts the speech, making the lower frequencies predominant. An attenuation equalizer is arranged to compensate for this effect and gives a greater attenuation of the low- than of the high-frequency waves. See ATTENUATION.

ATTENUATION FACTOR. Synonym for ATTENUATION COEFFICIENT.

ATTENUATOR. Network inserted in a line or between other networks to

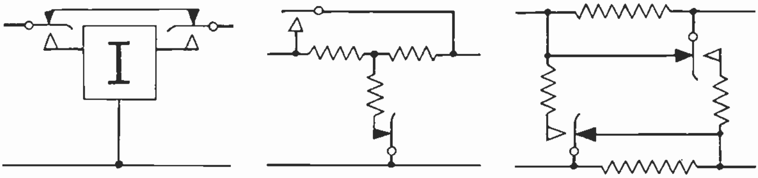


Fig. 50. Three methods of providing stepped adjustments to an attenuator network, in which attenuator pads are switched in by means of lever keys or switches. The use of a rotary switch for the purpose is illustrated in Fig. 51.

introduce a variable transmission loss without causing distortion at the same time. It is used for precise adjustment of the amplitude of a transmitted wave, usually for purposes of measurement, and is calibrated in decibels or decinepers. As well as having variable attenuation, an attenuator is so designed that its insertion does not change the impedance of the circuit, in contrast with an attenuator pad, which introduces a fixed loss and may be used to match together two circuits of different impedance.

Attenuators most commonly consist of a series of attenuator pads of the resistive type, using π- or T-networks for unbalanced circuits and H- or O-networks for balanced circuits. Figures for calculating the values of resistive network elements in terms of the magnitude *Z* of the characteristic impedance of the circuit are shown in the table at Fig. 49.

The attenuation is adjustable in discrete steps by means of lever keys or switches (Fig. 50). In another type (Fig. 51), the attenuator consists, in effect, of an infinite artificial line; the output is taken from one end, whilst the input is applied to one of a number of intermediate points of the line by means of a multi-point rotary switch. The input power divides at the point of entry to the artificial line and flows equally in each direction. Also, half the input power is dissipated in the impedance-matching series resistor. The maximum output power is therefore only one-quarter of the input power and the minimum attenuation is approximately 6 db.

The latter type may be adapted to provide continuously variable attenuation by making the series resistors a continuously wire-wound element in contact with a wiper or slider. When the moving contact is in between the junction points of the parallel resistors, there is some departure from linearity of scale and constancy of impedance; but this effect is not harmful in some applications, such as volume faders and mixers.

In order to be free from distortion, all the elements of an attenuator network must be of the same kind, either resistive, inductive or capacitive. Resistive types are satisfactory at audio frequency and, if carefully designed, up to medium radio frequencies. Above these frequencies, capacitive attenuators are sometimes used. Inductive attenuators are comparatively rare.

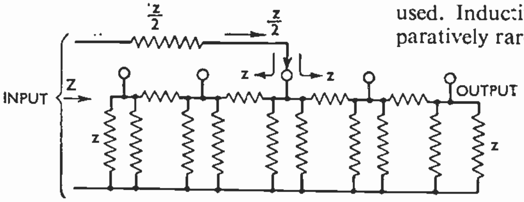


Fig. 51. Diagram showing attenuation adjustment by the use of a multipoint rotary switch.

The stray capacitance and inductance associated with switch-type attenuators, which control the upper working limit of frequency, are equally troublesome with capacitive and inductive types. For this reason, capacitive and inductive attenuators usually consist of a single network with one or two variable elements. This method of adjustment suffers from the defect that the network ceases to be of constant impedance; but by suitable precautions in design, either the input or the output impedance can be made substantially independent of attenuation setting.

AUDIBILITY. In terms of loudness, the range of sound which can be heard by the human ear. The range extends from the threshold of hearing, at which a sound is just audible, to the threshold of feeling, where the intensity of the sound causes physical pain. See SPEECH AND HEARING.

AUDIO FREQUENCY. Wave frequency which lies within the AUDIO RANGE (q.v.).

AUDIO-FREQUENCY AMPLIFIER. Apparatus, circuit or valve which amplifies signals at audio frequency, usually taken to range from 30 to 10,000 c/s. However, the limits are difficult to define; those just quoted are certainly desirable for high-fidelity reproduction, but for less exacting purposes a range of 50–5,000 c/s is adequate.

Unlike the great majority of radio-frequency amplifiers, the audio type is designed to cover a wide range of frequencies with equal efficiency. Apart from any special corrections to suit particular circumstances, the frequency-response graph of a good audio-frequency amplifier is something approaching a straight line over the range of audible frequencies. See AMPLIFICATION, AMPLIFIER.

AUDIO-FREQUENCY TRANSFORMER. Transformer used in circuits which handle waves lying within the audio-frequency band. See TRANSFORMER.

AUDION. Name, now seldom used, given by Lee de Forest, the inventor of the triode, to the first valve which contained anode, cathode and control grid.

AUDIO OSCILLATOR. Instrument designed to produce oscillations at audio frequency. It is used extensively in testing the performance of audio-frequency amplifiers. Such an instrument usually contains a variable component enabling any frequency within the audible range to be selected. See OSCILLATOR.

AUDIO RANGE. Term given to the complete range of frequencies which can be detected by the normal human ear. The lower limit of the range is usually taken as 16 c/s and the upper limit as 20,000 c/s. See SPEECH AND HEARING.

AUSTIN-COHEN FORMULA. Formula for calculating the signal strength of low-frequency waves at long distances from the sender. The electric field strength to be expected at distances of up to 300 miles from the sender is given approximately by the formula:

$$V \text{ (volts per metre)} = \frac{377hI}{\lambda d},$$

where h is the effective height of sending aerial (metres), I the current in sending aerial (r.m.s. amperes), λ the wavelength in metres, and d the distance from the sender (metres).

This formula makes no allowance for absorption losses suffered during long-distance propagation; to allow for such losses, Austin and Cohen added an exponential factor, $\varepsilon^{-ad/\sqrt{\lambda}}$, where ε is the base of the Napierian logarithms, a the constant (0·0015 for transmission over sea water), d the distance from sender in kilometres and λ is the wavelength in kilometres.

The full formula for the field strength at a distant point thus becomes:

$$V = \frac{0{\cdot}377 \times 10^6 \times Ih \times \varepsilon^{-ad/\sqrt{\lambda}}}{\lambda d}$$

micro-volts/metre, where h, λ and d are in kilometres.

The Austin-Cohen formula cannot

be applied to the ionospheric wave which is relatively less-attenuated than the ground wave. See ABSORPTION, FIELD STRENGTH, GROUND RAY.

AUTO-CAPACITIVE COUPLING. Coupling of two circuits by a capacitor common to both circuits. See COUPLING, FILTER.

AUTO-CAPACITY COUPLING. Synonym for AUTO-CAPACITIVE COUPLING.

AUTODYNE. Synonym for AUTOHETERODYNE.

AUTODYNE OSCILLATOR. See AUTOHETERODYNE OSCILLATOR.

AUTOHETERODYNE. Beat-frequency reception arrangement in which the local oscillations are generated by a valve which also serves as the detector. This system is commonly used for reception of type A1 waves, although it involves some detuning of the detector circuits in order to produce the desired beat-frequency.

On the higher frequencies, this detuning is not serious, since the beat-frequency represents but a small fraction of the signal-frequency. See BEAT FREQUENCY, BEAT RECEPTION.

AUTOHETERODYNE OSCILLATOR. Valve which performs the dual function of detection and generation of local oscillations for beat reception. See BEAT-FREQUENCY OSCILLATOR, BEAT RECEPTION.

AUTOMATIC ALARM. Alarm device, such as an electric bell, buzzer or lamp, operated by the automatic making or breaking of an electrical contact when an emergency occurs. The principle is applied in many different forms, each being designed to serve a particular purpose.

AUTOMATIC-CALL DEVICE. In radio telegraphy, a receiver which incorporates a series of relays designed to operate only when signals of a predetermined formation are received. The device is fitted to ships on which constant radio watch is not maintained, the apparatus operating on receipt of distress signals and ringing alarm bells to attract the operator's attention.

AUTOMATIC DIRECTION-FINDER. Direction-finder in which some or all of the operations normally performed manually are done automatically by the equipment. A simple example is the cathode-ray direction-finder. With this, the operator is not required to rotate a loop or other pivoted aerial-system, nor the search coil of a goniometer, to determine the bearing of the station whose signals he is picking up; instead, the bearing appears automatically on the tube screen and is read off a scale of degrees mounted round its rim (see CATHODE-RAY DIRECTION-FINDER).

In a more elaborate system, a rotating direction-finding beacon radiates a television signal which conveys a simple picture of the figures giving its bearing from moment to moment as it rotates. By noting the characteristic variation in the signal, the receiving operator can decide the instant at which the beacon is aimed directly towards him and, by noting the figures then being televised, can determine his bearing.

Still more elaborate devices to give automatic readings are in use in certain forms of radio compass. Continuously revolving, power-driven loop aerials or goniometers are used in some of these, with various electrical devices which cause the correct bearing to be displayed on a dial or other suitable indicator. See DIRECTION-FINDER, DIRECTION-FINDING.

AUTOMATIC FREQUENCY-CONTROL. Circuit arrangement for maintaining an oscillator at or close to a predetermined frequency; or for adjusting it to that frequency when brought near to it by some automatic tuning device, such as a press-button system.

Such arrangements may be found in sender circuits, where their purpose is to minimize drift of carrier frequency, or applied to the local oscillator of a superheterodyne receiver to correct small errors in tuning. See FREQUENCY DISCRIMINATOR.

AUTOMATIC GAIN-CONTROL. Arrangement for holding a radio receiver's output at a substantially constant level despite considerable fluctuations in the strength of the incoming signal.

Satisfactory listening demands that, once a signal has been set at a suitable level of loudness, it shall remain at that level without need of further adjustment. Convenient operation of a radio receiver requires that it can be tuned from station to station by means of a single control, without manipulation of gain. A manual form of gain control meets neither of these requirements, for it needs constant adjustment to maintain a uniform level of output if the transmission is subject to fading, and it commonly requires re-setting when changing stations.

Attempts to provide an automatic control of the output level were made in quite early days of radio, but little success was possible until variable-mu valves were introduced. These valves have the property that their gain is directly controllable by variation of grid-bias voltage. And they do this without giving the undesirable effects which would result if the same type of control were attempted with valves of the normal or non-variable-mu type.

With such valves in the radio- and/or intermediate-frequency amplifier of a receiver, it can be seen that there is at once a possibility of truly effective automatic gain-control. All that is needed is to derive from the signal a voltage proportional to its average amplitude, and apply this to the grids of the variable-mu valves in such a way that, as the signal grows stronger, the special bias voltage reduces the amplification of the valves to compensate as nearly as possible for the fluctuations.

It is well to admit at this point that perfect constancy of output is impossible with any simple device; there must be *some* alteration to enable the automatic gain-control to function at all. What the device can, in fact, do is to ensure that the variations in output level are too small for the human ear to detect.

A suitable voltage for this modern form of automatic gain-control can be obtained by rectifying a type A3 signal at some suitable point in the receiver. A unidirectional voltage proportional to the signal strength will thus be obtained. The modulation of the carrier will seem, at first glance, to introduce a complication, because it will naturally appear in the rectified voltage, just as it does in the case of a detector valve.

If the rectified voltage that we intend to use for gain control were allowed to follow the modulation, the result would be an undesirable form of negative feedback. This can be prevented by introducing a simple filter circuit into the system (Fig. 52). If the filter is suitably proportioned, it will smooth out the audio-frequency variations in the rectified carrier voltage, but will still permit this voltage to follow the slower changes in carrier amplitude due to fading.

The filter usually consists of two components only: a series resistor and a reservoir capacitor. The values are

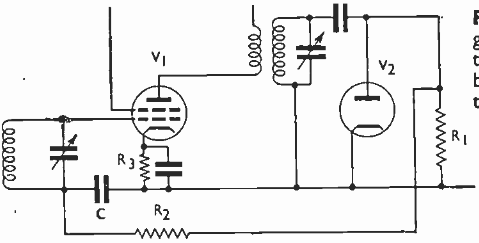


Fig. 52. Principle of automatic gain-control. Signal voltages in the output of V_1 are rectified by V_2 and appear across R_1; they are then passed to the grid circuit of V_1 via the filter R_2,C, so adding to the normal bias provided by R_3 a further negative voltage proportional to signal strength.

not critical, but should be such that the time-constant of the combination is several times longer than a half-cycle of the lowest modulation frequency likely to be encountered. Where automatic gain-control is applied to more than one stage in the receiver (as is usual), a separate filter will generally be provided for each valve. These are sometimes combined with voltage-dividing arrangements which cause each valve to receive a different amount of control voltage, according to the ideas of the particular designer.

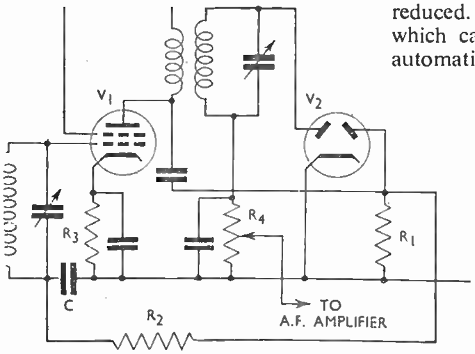


Fig. 53. In practice a double-diode may be used for detection and automatic-gain-control rectification. The arrangement, which may be compared with Fig. 52, is shown in outline only. R_4 provides both load resistance for the detector and gain control for the A.F. amplifier which follows.

The rectified voltage for gain-control purposes is usually derived from that point in the receiver at which the signal has undergone the maximum of amplification at radio or intermediate frequency before detection. For example, in a superheterodyne receiver (probably the only type of receiver in which automatic gain-control can be used to the fullest advantage), this means the final circuit of the intermediate-frequency amplifier; the same circuit, in fact, as that which feeds the detector.

A separate rectifier is normally used to supply the gain-control voltage, often in the form of a second diode in the same envelope as the detector (Fig. 53). A favoured arrangement, for instance, is that in which a double-diode-triode provides detection, automatic gain-control rectification, and a stage of audio-frequency amplification.

The behaviour of a receiver fitted with a fully effective system of automatic gain-control is somewhat modified basically. It tends to give a uniform level of output on the majority of transmissions, and fading is much reduced. (Except the high-speed variety, which causes a distorted signal; the automatic control cannot follow this for reasons which will be apparent from what has been said about the filtering of the control voltage.) Instead of causing a fall in the output level, deep fades merely produce a rise in background noise, the natural result of the increase in gain which countered the fade.

Again, a receiver with full automatic gain-control does not exhibit that sharp peaking of the signal at a given reading on the tuning dial which is characteristic of a highly selective set without the automatic control. Instead, the signal is heard at almost uniform strength over a narrow range on the dial, although it will tend to be of unsatisfactory audio quality at settings not near the centre of the range.

To enable the unskilled user to locate the centre point with greater ease, many of the more elaborate broadcast receivers are fitted with some sort of tuning indicator. In this way, the designer hopes to induce the operator to set the tuning correctly, and so enable the receiver to give the highest fidelity of reproduction of which it is capable. See GAIN CONTROL.

AUTOMATIC GRID-BIAS. Grid bias obtained by connecting a resistor and capacitor in parallel in the grid circuit of a valve (Fig. 54a). When alternating potentials are applied between grid and cathode, the resulting grid current flowing in the resistor causes the grid to be negatively biased (see GRID-LEAK). The term is also applied to circuits in which a resistor is connected between the common cathode of a valve or valves and high-tension negative (Fig. 54b).

AUTOMATIC SIGNALLING. In telephony, a system with which calling and supervisory signals are automatically transmitted when the circuit is set up or released.

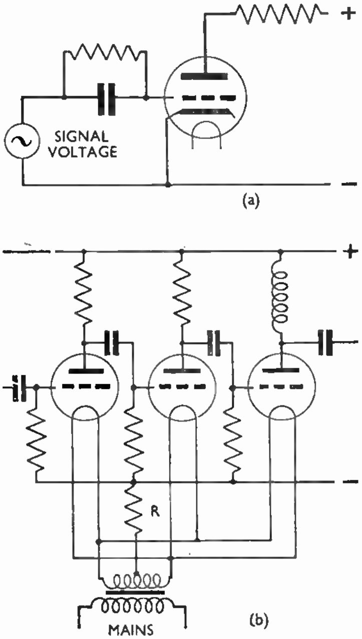


Fig. 54. Automatic grid-bias given (*a*) when the signal voltage causes the grid of the valve to become positive in respect of the cathode, and (*b*) by the resistor *R* in which the cathode currents of all the valves flow, thus putting the three cathodes at the same potential above earth.

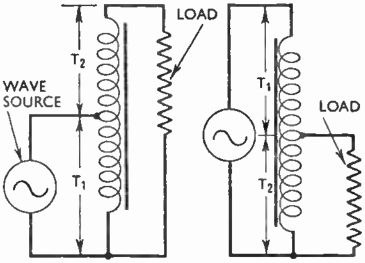


Fig. 55. Voltage transformation ratio of an auto-transformer is equal to the number of turns in the wave-source circuit (primary) to the number of turns in the load circuit (secondary); thus, in (*a*) it is $T_1 : (T_1 + T_2)$, and in (*b*) $(T_1 + T_2) : T_2$.

AUTOMATIC TUNING-CONTROL. Circuit arrangement for maintaining an oscillator at or close to a chosen frequency; *or* mechanical arrangement for tuning apparatus to a pre-selected frequency at a certain time, as in automatic watching systems. The latter is the more usual sense. See AUTOMATIC FREQUENCY-CONTROL.

AUTOMATIC VOLUME-CONTRACTOR. See COMPRESSOR.

AUTOMATIC VOLUME-CONTROL. Synonym for AUTOMATIC GAIN-CONTROL.

AUTOMATIC VOLUME-EXPANDER. See EXPANDER.

AUTO-TRANSFORMER. Transformer with one winding, the transformation of voltage and current being between one pair of tappings and another pair on the same winding (Fig. 55). Provided all the turns on the winding are so coupled that there is no leakage of flux, voltages in the whole of the winding will be induced by passing an alternating current through part of the winding. The turns ratio of the transformer is the ratio of the turns included in one circuit to those included in the other circuit.

The advantages of the normal transformer over the auto-transformer are: first, that it is easier to ensure close coupling with two distinctly separate windings; and, second, that it is often of great advantage to be able to isolate circuits in respect of D.C. connexion, but to couple them as regards A.C. On the other hand, the auto-transformer may be a cheaper form of construction. See TRANSFORMER.

AUXILIARY GRID. Grid electrode of a valve used as a control grid in conjunction with another control grid. A valve may be specially designed to contain an auxiliary control grid; alternatively, the screen grid of a normal pentode or tetrode may be employed as an auxiliary control grid. See CONTROL GRID, DUAL-GRID VALVE PENTODE. SPACE-CHARGE-GRID VALVE, WUNDERLICH VALVE.

AVAILABLE GRID SWEEP. Total excursion of grid voltage about the grid-bias voltage which can be swept through without causing distortion. See GRID SWEEP.

A.V.C. Abbreviation for AUTOMATIC VOLUME-CONTROL.

AZIMUTH. Synonym for TRUE BEARING.

B

BACK-ELECTROMOTIVE FORCE. Phenomenon which opposes the normal flow of an electric current. A typical example is that of a current increasing in a circuit containing inductance; the increasing magnetic field induces a voltage in the circuit which opposes the applied voltage and thus delays the growth of current. A related phenomenon occurs when a current begins to fall in such a circuit; the collapsing magnetic field then generates a voltage which tends to maintain the current and so delays its fall.

BACKGROUND NOISE. See RANDOM NOISE.

BACKLASH. Synonym for REVERSE GRID CURRENT.

BAFFLE. Form of sounding-board used to improve radiation of sound energy from an electrical reproducer such as a loudspeaker. It consists of a single-plane structure, with the diaphragm or cone of the reproducer usually placed at the centre, as shown in Fig. 1. Its purpose is to minimize interaction between frontal and back radiations from the reproducer, which tend to cancel each other at low frequencies, producing attenuation.

Ideally, the dimensions of the baffle should be such that its perimeter is twice the wavelength of the lowest frequency to be reproduced. See BOX BAFFLE.

BAKELITE. Proprietary name for synthetic resin formed from formaldehyde and cresol or phenol. It is used for insulators and in varnishes and plastics products.

BALANCED ADCOCK DIRECTION-FINDER. Adcock direction-finder derived from the elevated type (see ELEVATED H-TYPE ADCOCK DIRECTION-FINDER), but differing in that

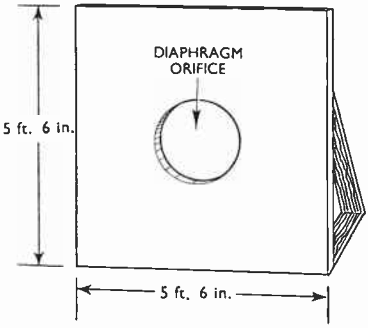


Fig. 1. Rectangular loudspeaker baffle for ideal reproduction when the lowest audio frequency required is 100 c/s. With a smaller baffle, some attenuation at very low frequencies is inevitable.

the lower section of each vertical dipole is replaced by a connexion to earth through a balancing-impedance network (Fig. 2). The aim of the modification is to obviate the need for raising the receiver building to the level of the dipole centres as is done in the elevated-H type.

BALANCED ARMATURE. In a moving-iron loudspeaker or gramophone pick-up, an armature pivoted at or near its centre of gravity, both ends of the armature moving in a magnetic field. See GRAMOPHONE PICK-UP.

BALANCED CIRCUIT. Circuit symmetrically disposed with respect to a point of zero or constant potential. In a balanced circuit, the sum of the potentials at similar points, symmetrically disposed about the steady potential point, is zero. Another definition postulates that, if the input and output terminals are changed over simultaneously, it will make no difference to circuits external to, and connected to, the balanced circuit. In a balanced circuit, one part of the circuit forms the mirror image of the other. Thus, if one half of the circuit is drawn, and a mirror placed along the earth potential line, the mirror shows the other part of the balanced circuit.

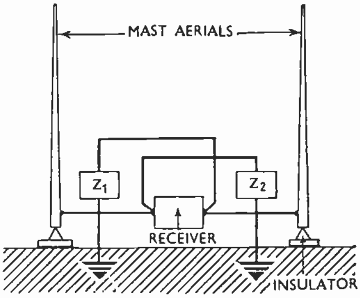


Fig. 2. One of the two pairs of mast aerials which comprise a balanced Adcock direction-finder system; Z_1 and Z_2 are the balancing impedances.

In Fig. 3, diagrams (a), (b) and (c) show the evolution from unbalanced to balanced circuit for equal load power of a quadripole with series impedances Z_1, Z_3 and shunt impedance Z_2; (b) and (c) differ only in that the shunt arm in (c) is $Z_2 = Z_2/2 + Z_2/2$ of (b), and the load resistance in (c) is $R = R/2 + R/2$ of (b). The full line of (b) is a connexion to zero potential. The dotted line of (c) shows the zero-potential region; the electrical centre point of R in (c) could be connected to earth, as could be the electrical centre of Z_2, without disturbing conditions.

Diagrams (d), (e) and (f) of Fig. 3 show the distinction between balanced and unbalanced valve connexion. The valves in (e) and (f) presumably each absorb less power than that in (d) because of the assumption that the load power is the same in the case of balanced and unbalanced circuits.

Balanced circuits are uneconomical in the use of components, but circumstances may compel their use. Thus, if balanced transmission lines are generally used, the currents in the two conductors are made to flow in opposite directions and the external field is, ideally, zero. Moreover, a balanced transmission line is automatically protected against the effects of external stray fields which induce equal and opposite voltages in the two conductors.

It is, therefore, sometimes necessary that terminal apparatus joined to a transmission line shall be balanced in order to feed into a balanced line. For this purpose, the transformer is of great value as it can easily change an unbalanced to a balanced circuit. Transformers, however, cannot be used when the ratio of maximum to minimum frequency of the waves is very high, or when the maximum frequency is extremely high. Some valve circuits can be used to change from balanced to unbalanced conditions, and will function equally well over a wide frequency band. See BALANCED QUADRIPOLE, CATHODE FOLLOWER, UNBALANCED CIRCUIT.

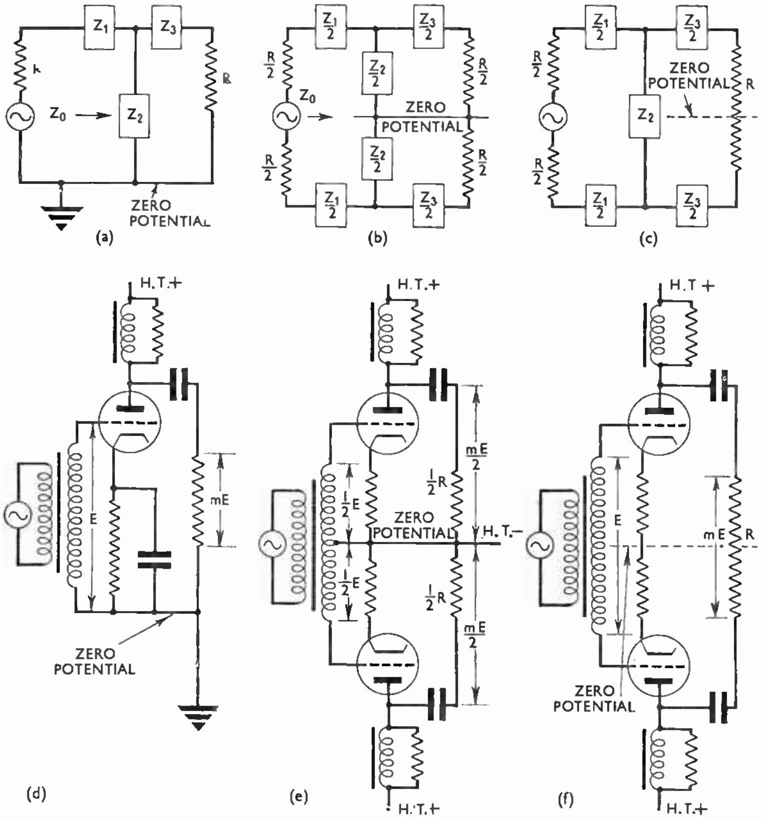


Fig. 3. Distinction between unbalanced and balanced circuits and between unbalanced and balanced valve connexions. All the diagrams assume that the power in the load resistance *R* is the same for unbalanced and balanced circuits.

BALANCED FEEDER. Connexion between aerial and sender or receiver comprising two conductors having equal capacitance to earth. See FEEDER.

BALANCED MICROPHONE. Microphone with three electrodes of which the centre one—that attached to the diaphragm—is earthed, the outer electrodes being connected to the two ends of the primary winding of a centre-tapped microphone transformer (Fig. 4). This arrangement provides a push-pull input to the microphone amplifier. See CARBON MICROPHONE.

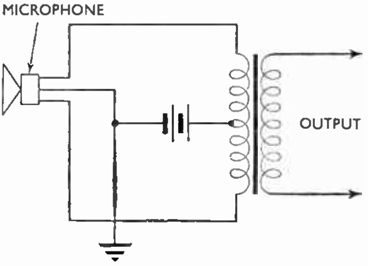


Fig. 4. Connexion details of the three electrodes in a balanced microphone.

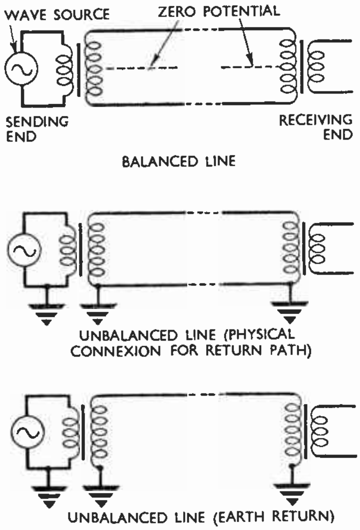


Fig. 5. Diagrams showing the difference between balanced and two forms of unbalanced transmission lines. All lines used in telephony and telegraphy are balanced to prevent both the radiation of waves from them and the induction in them of voltages from stray fields.

BALANCED QUADRIPOLE. Quadripole connected as a balanced circuit. In other words, a quadripole such that the input terminals can be interchanged, and the output terminals similarly interchanged, without affecting the circuit external to the network.

BALANCED TRANSMISSION LINE. Transmission line in which the two conductors are at equal and opposite potentials above and below zero potential when the line is used to transmit intelligence. More accurately, a balanced transmission line is one in which the input terminals can be interchanged, and the output terminals simultaneously interchanged, without affecting the circuit external to the line. Fig. 5 may help to show more clearly the difference between a balanced and unbalanced transmission line. See BALANCED CIRCUIT.

BALANCED VALVE-AMPLIFIER. Amplifier containing a pair of similar valves, or a double valve, so connected that the control grids receive voltages which are of equal amplitude but of opposite phase, the outputs being combined in a balanced output circuit. See BALANCED VALVE-OPERATION.

BALANCED VALVE-OPERATION. System of operation in which an amplifying stage consists of a pair of valves so arranged that each carries only half the signal; their outputs are combined in proper phase to reconstitute the signal. The essential feature of the balanced valve system is that the signal is split and the halves which are applied to the grids of the two valves are in opposite phase. Thus, if at a given instant the signal is making the grid of one valve negative, it will be sending the grid of the other positive.

The balanced system is easiest to understand in its earliest form, originally known as a push-pull circuit, in which the signal is split by means of an intervalve coupling transformer with a centre-tapped secondary winding; the centre point is earthed through the grid-bias circuit and the two ends of the winding are connected to the

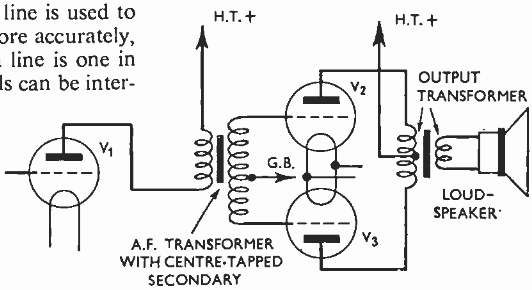


Fig. 6. Elements of a balanced valve A.F. amplifying stage, in which V_2 and V_3 are the balanced, or push-pull, output valves.

respective valve grids (Fig. 6). In a similar manner the complementary anode currents of the two balanced valves are recombined with an output transformer with a centre-tapped primary. This system is still used.

As in all balanced-operation output circuits, since each valve carries only half the signal, its power-handling capacity can be considerably smaller than that which would be required in a valve to handle the same signal single-handed. Moreover, in the balanced circuit certain forms of distortion due to overloading tend to cancel out in the two halves of the stage, and so it can be "driven" a little harder than would be permissible if the valves were used separately.

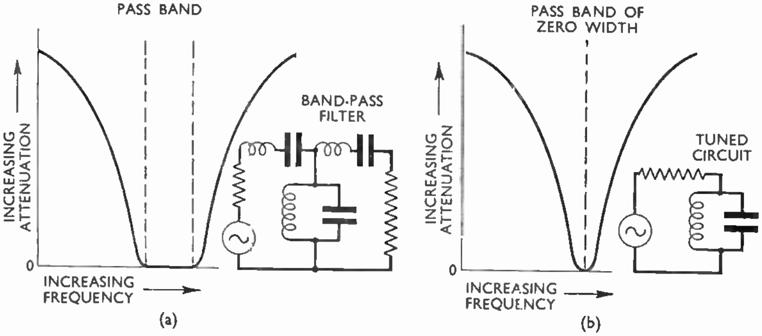


Fig. 7. Graphs distinguishing between the effect of using a band-pass filter (*a*) and a selective tuned circuit (*b*). Assuming that reactive elements in both cases have zero loss, the former provides theoretically zero attenuation over a band of frequencies, while the latter gives it at only one frequency.

The balanced system is at first sight difficult to apply where the intervalve-coupling device is a resistance, but various ingenious solutions have been devised. See PHASE SPLITTING.

BALANCING AERIAL. Aerial employed to pick up any undesired signal, which is then fed into the main receiving circuits in phase opposition to balance out the effects of the interference. The balancing aerial might be, for instance, a loop whose directive properties enable it to pick up strongly the unwanted signals while deriving but little voltage from the wanted signal.

BALANCING CAPACITOR. Capacitor connected so as to perfect the balance of a line. Sometimes, notably in open-wire lines used for telegraphy, the line is unbalanced due to asymmetries of construction or of insulation. In such cases, a balancing capacitor is connected to the line to improve the balance.

BALANCING CONDENSER. Synonym for BALANCING CAPACITOR.

BALANCING NETWORK. Network designed to simulate the impedance presented by a line or another network (see ARTIFICIAL LINE). In telegraphy, a balancing network is known as a duplex balance.

BALLAST RESISTOR. Resistor having a high temperature coefficient of resistance and used to maintain a substantially constant current in, for example, the heater circuit of an A.C./D.C. receiver. See BARRETTER.

B-AMPLIFIER. In a broadcast chain, the amplifier which follows the A- or microphone amplifier.

BAND ARTICULATION. In telephony, the percentage of speech-bands correctly received over the system, as compared with those transmitted. See ARTICULATION, SPEECH-BAND.

BAND-ELIMINATION FILTER. Synonym for BAND-STOP FILTER.

BAND FILTER. Synonym for BAND-PASS FILTER.

BAND-PASS FILTER. Filter which gives a relatively small attenuation to waves lying within a frequency band and larger attenuation to waves lying outside this "pass band." A band-pass filter composed of elements which gave no loss (zero power factor) ideally terminated, would give zero attenuation to waves lying in its pass band (see EQUALIZER, FILTER, FREQUENCY BAND, PASS BAND, TUNED CIRCUIT).

Theoretically, and sometimes in practice, a band-pass filter gives equal attenuation to waves of different frequency lying within the pass band. It is thus essentially different from the frequency-selective tuned circuit, which has a maximum response at only one frequency. This distinction is brought out in Fig. 7.

A distinction is sometimes made between band-pass filters in which the coupling is inductive, and those in which it consists of a reactance common to two circuits. The electrical similarity between so-called "directly coupled" and "indirectly coupled" band-pass filters is obvious; in an inductively coupled band-pass filter, the shunt impedance is the mutual inductance; in a directly coupled band-pass filter, it may be an inductive reactance, a capacitive reactance, or a combination of both (Fig. 8). The inductively coupled band-pass filter is used in the intermediate-frequency circuit of superheterodyne receivers and the directly coupled type is nearly always used in commercial transmission systems, broadcasting senders and so forth.

The response of the inductively coupled band-pass filter is determined by the resonant frequency, the value of the Q-factor and the coefficient of coupling of the two tuned circuits. If the two tuned circuits are tuned to the same frequency and have the same Q-factor value, increasing the coupling effects an increase in the frequency difference between two response peaks (Fig. 9).

The directly coupled band-pass filter can be made to give almost any shape of response curve, provided that the value of the reactive elements and of the Q-factor, the number of sections and the termination are correctly related. In some cases, quartz crystals are used instead of reactive elements.

The crystal element, while expensive, has an effective Q-factor value far greater than any combination of reactors; Q-factor values up to even 10,000 are possible and the ideal of a

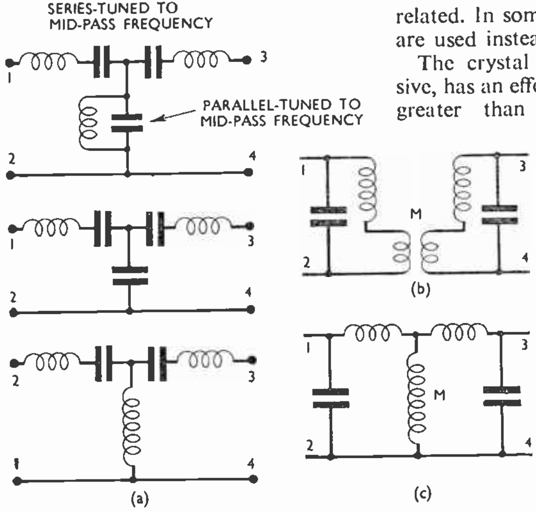


Fig. 8. Band-pass filters (*a*) are sometimes termed "directly coupled" to distinguish them from one that is inductively coupled (*b*) by mutual inductance *M*. Broadly, however, the mutual inductance may be considered as forming a direct coupling (*c*).

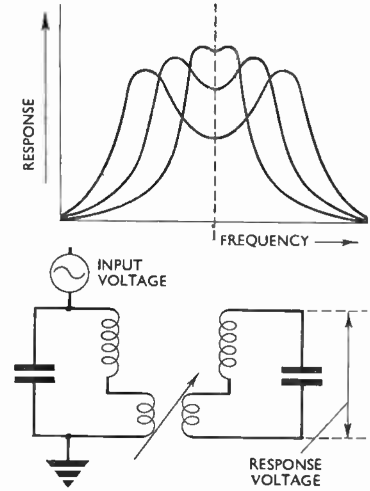


Fig. 9. Response graphs and band-pass filter. If two similar parallel-tuned circuits are separately tuned to the same frequency and then coupled together, the curves have double peaks.

low-loss filter element is the more nearly achieved. See COUPLING COEFFICIENT, QUARTZ CRYSTAL, REACTOR, SUPERHETERODYNE RECEIVER.

BAND-PASS TUNING. Tuning which produces a somewhat flat-topped resonance curve and, hence, gives more even response to a band of frequencies than do circuits having a sharply peaked graph (Fig. 10).

Sharp-peaked curves tend to attenuate high modulation frequencies in a carrier wave, with ill effects on quality of speech and music, or on definition in television pictures. Band-pass tuning can be arranged to give a substantially even response over the required band of frequencies; moreover, the sides of such a flat-topped curve tend to fall away more steeply, with beneficial effect on general selectivity.

Band-pass effects are usually obtained by means of a suitable degree of magnetic and/or capacitive coupling between a pair of tuned circuits, the width and flatness of the curve's top depending on a suitable adjustment of the coupling. The effect, indeed, is one of an approach to the double-humped curve which is characteristic of tightly coupled circuits.

The separation of the pair of incipient peaks which form the flattened top is given by $f = \frac{\sqrt{\omega^2 M^2 - r^2}}{2 \pi L}$, where f, the separation frequency, is in cycles, M is the mutual inductance in henrys, r is the radio-frequency resistance, L is the inductance in

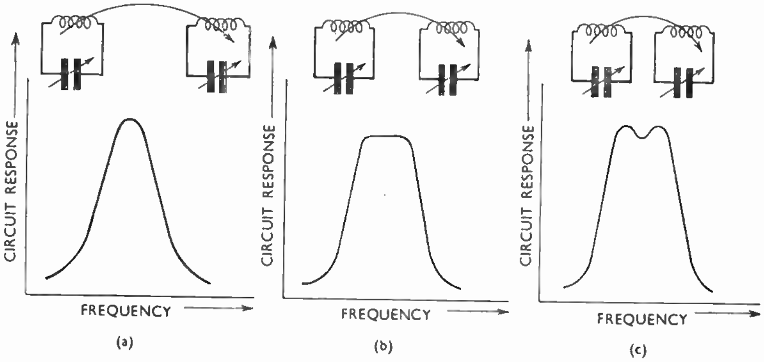


Fig. 10. Two loosely coupled circuits (*a*) give a narrow-peaked resonance curve like that of a single low-decrement type of circuit. With closer coupling, however, they give the flat-topped "band-pass" type of curve (*b*). If the coupling is still further increased (c), a double-humped curve is developed.

henrys, and ω is 2π times the natural frequency of the tuned circuits.

This expression, which applies to magnetic coupling, demonstrates that the width of the curve varies with frequency, becoming wider at the higher frequencies. A generally similar formula for capacitive coupling shows a similar effect when the coupling capacitor is connected as in (a) of Fig. 11, but an opposite one when it is placed as in (b). By skilful combination of these various coupling methods the designer can produce a response graph which remains of substantially equal width over a considerable tuning range. See COUPLING, RESONANCE CURVE.

BAND-REJECTION FILTER. Synonym for BAND-STOP FILTER.

BAND RELAY. Synonym for PUBLIC-ADDRESS SYSTEM.

BAND REPEATER. Synonym for PUBLIC-ADDRESS SYSTEM.

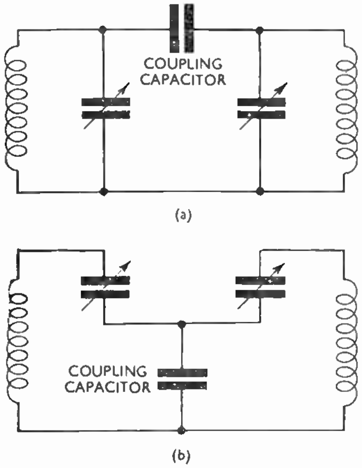


Fig. 11. Method of overcoming, in band-pass tuning, the tendency of coupling devices to vary in efficiency with frequency. In (*a*) the coupling capacitor tightens the coupling at higher frequencies, while in (*b*) it produces the opposite effect; by combining the two a substantially constant band width can be obtained.

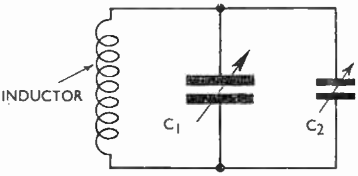


Fig. 12. In the band-spreading system of tuning, a large capacitor C_1 is employed to make approximate adjustments, and a smaller one C_2 to cover each particular band of frequencies.

BAND SPREADING. Common device in short-wave receivers that facilitates tuning adjustments by provision of a small variable capacitor in parallel with the principal tuning capacitor.

Without some such expedient, short-wave tuning tends to be excessively critical, since a variable capacitance large enough to cover an adequate wave band on each coil unit is also large enough to demand extremely accurate adjustment. A much smaller variable capacitor is, therefore, placed in parallel with the main one, as shown in Fig. 12, so that, as the latter is set to certain major reference points on its scale, each small band of frequencies can be spread over the dial of the former.

BAND-STOP FILTER. Filter which gives a relatively large attenuation to waves lying within a certain frequency band, and a smaller or theoretically zero attenuation to waves lying outside this stop band. If the filter elements give no loss (power factor zero) and the filter is ideally terminated, the attenuation in the stop band would be infinite. This infinite attenuation may be given for a wave of a certain frequency or for waves lying within a frequency band. Fig. 13 shows two types of band-stop filter and the resulting response curves. It is assumed that both have ideal elements and are ideally terminated. Note that the less complex type gives infinite attenuation at only one frequency, whereas the other gives infinite attenuation over a frequency band.

If the term filter is used to describe only those networks containing purely reactive elements, whatever the nature of the termination, then the band-stop filter is restricted to the forms illustrated. Certain resistance-capacitance networks, and tuned circuits associated with resistors, are sometimes loosely classified as band-stop filters; other such networks, performing the same function in a different way, are described under different headings. See ACCEPTOR CIRCUIT, FILTER, NULL NETWORK.

BAND SWITCHING. System of switching, usually of coil units, to enable a receiver or other apparatus to function on more than one band of frequencies. In modern radio receivers, the wave-band switching is somewhat complex since, to pass from one wave band to another, the constants of several circuits must be altered simultaneously. The required multiple switches are usually linked on a single spindle and often give a complete change-over between separate coil units, as indicated in Fig. 14.

BARKHAUSEN-KURZ OSCILLATIONS. See ELECTRONIC OSCILLATIONS.

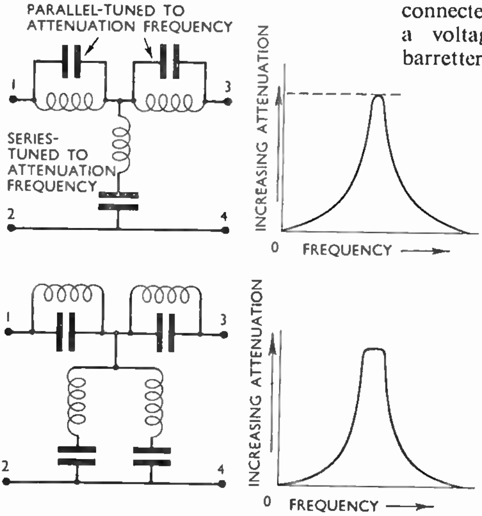


Fig. 13. Two types of band-stop filter and the resulting attenuation graphs. It is assumed that the reactive elements have no loss, and that the filter is ideally terminated

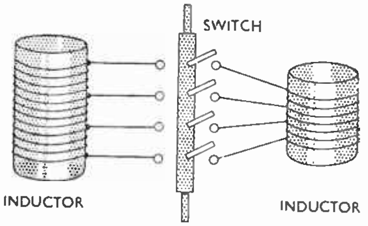


Fig. 14. Purely diagrammatic representation of band switching with a multiple switch, usually of the rotary type.

BARKHAUSEN OSCILLATOR. Generator of oscillations having a frequency above 100 Mc/s.

BARREL DISTORTION. Intermodulation between X and Y deflector systems in a cathode-ray tube, causing, for example, a picture to be distorted as shown overleaf in Fig. 15. It is due to non-uniformity of the deflecting fields.

BARRETTER. Form of ballast resistor for maintaining in a circuit a substantially constant current, in spite of a varying applied voltage or a varying potential drop inside the circuit. A common application is in A.C./D.C. receivers where the valve heaters are connected in series with each other, a voltage-dropping resistor and a barretter, all across the supply mains.

The barretter consists, usually, of an iron-wire filament in a hydrogen-filled glass envelope, and has the appearance of a small incandescent lamp. The iron filament has a high value of temperature coefficient of resistance, such that, over an appre-

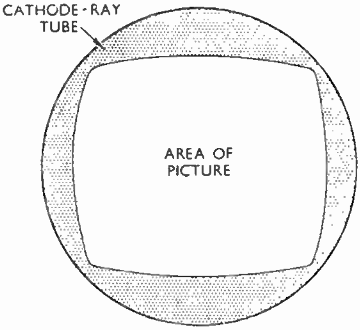


Fig. 15. Distorted shape of picture area on a cathode-ray-tube screen when barrel distortion is present.

ciable range of voltage, the current is substantially constant. A typical current-voltage characteristic is illustrated in Fig. 16.

The term barretter was also used to describe an early form of detector of high-frequency currents which operated by virtue of its change of resistance.

BARRIER-LAYER RECTIFIER. Rectifying type of photocell. It comprises two electrodes in contact; one is a conductor and the other is normally a relatively poor conductor of electricity. When the cell is exposed to light, a flow of electrons occurs across the contact between the electrodes, and rectification can, therefore, take place.

BASKET COIL. Coil for use as an inductor at radio frequencies wound on a special former consisting of a hub with an odd number of radial spokes.

The wire is wound spirally and passes from one side of one spoke to the opposite side of the next. The method is similar to that used for making the bottom of a circular basket, to which the finished coil bears some resemblance.

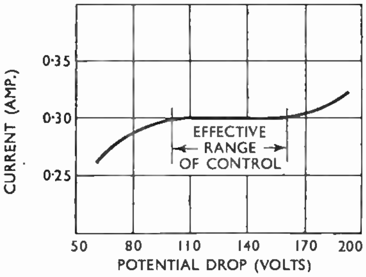
This type of coil, which can be made readily by hand, was popular in the early days of broadcasting. It has now fallen into disuse, however, and is superseded by machine-wound coils of the wave-wound or lattice-wound types. The object of the design is to minimize the capacitance between adjacent turns by limiting their close proximity to the points where they cross over.

BATTERY. Two or more cells, capacitors, resistors or other pieces of apparatus electrically connected in one circuit. The term is commonly used in connexion with a battery of cells rather than for resistors, capacitors, etc. To speak of "a battery" instead of "a cell" is a common error in terminology; a battery describes essentially a plurality of like things. See ACCUMULATOR CELL, HIGH-TENSION BATTERY.

BATTERY CHARGING. See ACCUMULATOR CHARGING. (Inasmuch as the term "battery charging" may well mean the charging of a battery of accumulators, it may be correctly used; but, since accumulators have the unique property of being able to be charged, the term "*accumulator* charging" to describe the process seems preferable.)

BATTERY COUPLING. Method of valve coupling in direct-current amplifiers. See D.C. AMPLIFIER.

Fig. 16. Barretter and (*below*) a graph showing characteristics. It will be seen that the current is substantially constant over a voltage range of approximately 100-160.



BATTERY ELIMINATOR. Mains unit for domestic receivers used for the reception of broadcast programmes. The term is more properly used when the mains unit is not a part of the receiver proper, but rather a separate assembly.

Early broadcast receivers were energized from separate high- and low-tension batteries. In some cases it was convenient to get rid of the batteries and replace them by a unit energized from the mains; this gave a direct-current supply of 150–200 volts, which replaced the high-tension battery, and a low-voltage alternating supply to feed the heaters and do away with the low-tension battery. The term "battery eliminator" for this unit was obviously appropriate.

B-BATTERY. Synonym for HIGH-TENSION BATTERY.

BEACON DIRECTION-FINDER. Form of sender radiating signals of such a type or in such a way that a distant receiving station can determine its bearing by listening to them. See AUTOMATIC DIRECTION-FINDER, NAVIGATIONAL AID.

BEAM. In light, a group of parallel light rays; in thermionics the stream of electrons emitted from the cathode of a valve or cathode-ray tube; in radio transmission, radiation from a directional aerial and confined within a certain angle.

BEAM AERIAL. See AERIAL-ARRAY.

BEAM APPROACH. See LORENZ BLIND-LANDING SYSTEM.

BEAM ARRAY. See AERIAL-ARRAY.

BEAM CURRENT. In a cathode-ray tube, the current which flows from the anode to the cathode and is carried by the electron beam which strikes the screen.

BEAM EFFECT. Differential focusing of high audio-frequency radiation from a loudspeaker, the diaphragm of which has a diameter similar to, or greater than, the wavelength of some of the sounds radiated.

BEAM POWER-VALVE. Tetrode, designed to overcome the effects of secondary emission, in which the electrons are concentrated into a beam. The essential feature of a beam power-valve is that a virtual cathode is formed between screen grid and anode (see VIRTUAL CATHODE). In a beam tetrode, this virtual cathode shields the screen grid from secondary electrons emitted by the anode (see SECONDARY EMISSION, TETRODE). The beam valve may be either a tetrode or pentode, but is more frequently a tetrode.

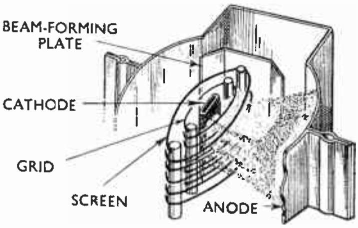


Fig. 17. Partly cut-away internal structure of a beam power-valve. In addition to the usual electrodes there are two beam-forming plates which help to concentrate the electrons in a uniform high-density beam.

Fig. 17 shows the electrodes of a beam-tetrode. Plates concentrate the electrons into a beam, and the screen and control grids are aligned (see ALIGNED GRID) so that the electrons are concentrated in sheets. The spacing between screen grid and anode is larger than in ordinary tetrodes and contains a concentration of electrons which constitute a virtual cathode.

The potential gradient in the space between anode and screen grid is such that secondary electrons cannot pass to the screen grid. The transition of the slope conductance from a high to a low value is more gradual in a beam power-tetrode than in a pentode. This is an advantage of the beam principle. See ANODE SLOPE-RESISTANCE, ANODE-VOLTS/ANODE-CURRENT CHARACTERISTIC.

BEAM SUPPRESSION. In television, the suppression of the electron beam during fly-back by the application of a large negative potential to the modulator electrode of the cathode-ray tube. See FLY-BACK.

BEAM SYSTEM. In radio communication, a system of transmission in which the carrier wave is directed along a narrow beam towards a specific reception point. The system serves two purposes; it secures a measure of secrecy, since messages can be picked up only at points along the beam, and by avoiding radiation in all unwanted directions a longer range is obtained for a given sender power-output.

BEAM TETRODE. See BEAM POWER-VALVE.

BEAM TRAP. Electrode in a cathode-ray tube employed to trap the electron beam when it is not required to excite the fluorescent screen.

BEAM VALVE. Valve, usually a tetrode, in which the electron stream is directed to the anode by deflector plates internally connected to the cathode. See BEAM POWER-VALVE.

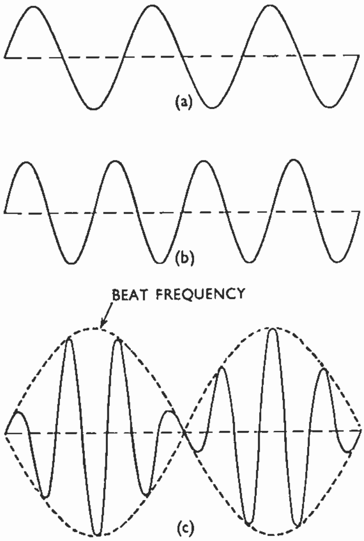


Fig. 18. The waves in (*a*) and (*b*) are of different frequencies (3:4); the result of adding together their amplitudes is shown at (*c*), where the envelope is the wave produced by beating.

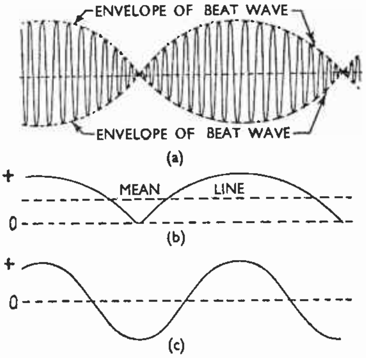


Fig. 19. When the typical wave produced by beating (*a*) is rectified, the result is as (*b*), which contains the fundamental and second harmonic; (*c*) is the fundamental component.

BEARING. Angle between the direction of some distant object and either true or magnetic north. The bearing is always reckoned from north through east; that is, clockwise round the compass scale, east being 90, south 180, west 270 and north 0 or 360 deg.

BEARING ERROR. Difference between the true bearing of a distant object and its bearing as determined by some apparatus subject to error, such as a direction-finder.

BEAT. One complete cycle of the variation of amplitude of a wave produced by BEATING (q.v.).

BEAT FREQUENCY. Frequency of the wave produced by BEATING (q.v.).

BEAT-FREQUENCY OSCILLATOR. Oscillation generator in which two R.F. oscillators are coupled together, producing a third oscillation the frequency of which is equal to the difference between the frequencies of the R.F. oscillators.

If the frequency of one R.F. oscillator is made variable, then beat-frequency oscillations of different frequencies may be obtained. For example, if one R.F. oscillator has a frequency of 50 kc/s and the other is variable between 50 kc/s and 60 kc/s, then oscillations having a beat frequency from 0 to 10,000 c/s can be produced. This is the principle of an audio oscillator working on the beat-frequency system.

BEATING. Production of a low-frequency wave by the interaction of two higher-frequency waves. The phenomenon of beating is not confined to radio; it occurs, for instance, with sound waves.

Almost everyone is familiar with the throbbing sound of multi-engined aircraft; this slow rising and falling of sound intensity is caused by beating between the sounds of engines which are not synchronized. Fig. 18 shows two waves of equal amplitude which are not of exactly the same frequency.

Adding the amplitudes of the two waves of (a) and (b) produces a wave of the form shown in Fig. 18c. The envelope of (c) is seen to rise and fall to form a wave in which the amplitude rises and falls. The wave formed by the resultant of adding together two waves is the wave produced by beating.

As seen from Fig. 19, the wave must be rectified before its amplitude variation can be appreciated. In the rectified-beat wave there is a strong second harmonic which gets smaller as the ratio of the amplitudes of the waves producing beating is increased. It may also be noted from Fig. 20 that any device, not necessarily a rectifier, which responds to power rather than to voltage or current also extracts the beat wave. Thus polarized telephones would not reproduce beats from the wave of Fig. 20a; unpolarized ones would. We hear beats because human ears do not respond linearly.

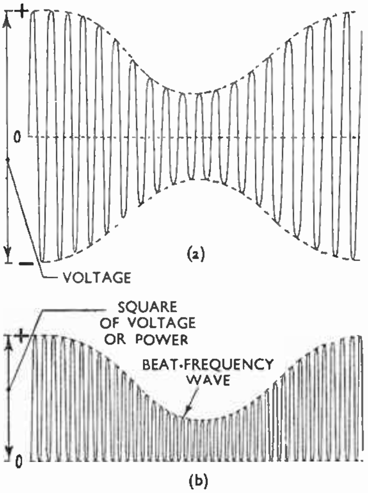


Fig. 20. Wave produced by beating (*a*) when two waves of slightly different frequency from which it is formed are also of different amplitudes; if (*a*) is passed through a power-integrating device, the wave (*b*) is produced.

The phenomenon of beating is used in beat reception. The beat-frequency oscillator was so called because, in its

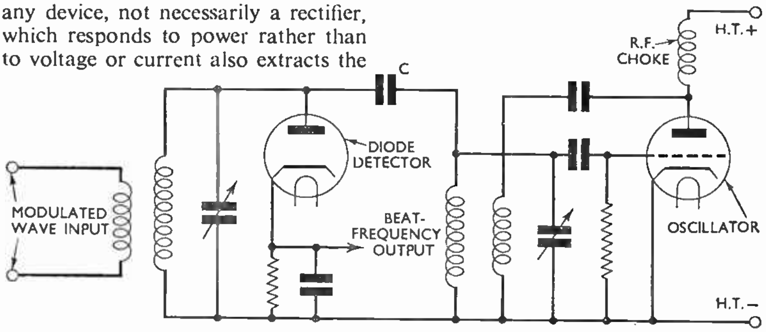


Fig. 21. One circuit arrangement of a beat oscillator used in a receiver to make C.W. (type-A1-wave) transmissions audible. *C* is a capacitor of about 2 $\mu\mu$F.

first form, a lower-frequency audio wave was produced by beating between higher-frequency waves. In modern practice, amplitude modulation is used to create lower- from higher-frequency waves. This is the distinction between beating and amplitude modulation, and between a beat oscillator and a beat-frequency oscillator. See BEAT FREQUENCY, BEAT OSCILLATOR, BEAT RECEPTION, FREQUENCY-CHANGING, MODULATION.

BEATING OSCILLATOR. Synonym for BEAT-FREQUENCY OSCILLATOR.

BEAT OSCILLATOR. Any oscillator the output of which is mixed with another wave to produce a difference or BEAT FREQUENCY (q.v.). Communications receivers contain a beat oscillator which is coupled to the detector circuit to produce an audible beat note with any signal wave present. In this way Morse transmissions of type A1 waves (C.W.) can be made audible (Fig. 21).

Certain A.F. generators make use of the beat principle. Basically, the generator consists of a fixed-frequency oscillator and a variable-frequency oscillator, both feeding into a frequency-changer stage where the beat frequency—the wanted A.F. output—is produced. The variable-frequency oscillator is adjusted to give the required beat frequency.

BEAT RECEPTION. System in which locally-generated oscillations interact with incoming signals to produce a new frequency. This important principle has many applications. In its typical form, it is used for reception of type-A1 Morse signals, which would produce merely a succession of clicks if submitted only to normal processes of amplification and detection, since they are not modulated, but are simply "chopped" into long and short bursts.

To generate an audible frequency from such signals, they are combined with a local oscillation of slightly different frequency, beats then occurring at the arithmetical difference of the two frequencies. This, after detection, gives an audible note equal to the beat frequency. See AUTO-HETERODYNE, BEAT FREQUENCY, BEAT OSCILLATOR.

BEATS. Characteristic sounds heard in one ear when two sounds having slightly different frequencies are produced. The effect is a rhythmic increase and decrease in the intensity of the combined sound. See BEATING.

BEL. Ten decibels. See DECIBEL.

BELLINI-TOSI AERIAL. Two aerials, usually of the loop type, arranged with their planes at right-angles and connected to the stationary windings of a goniometer in a BELLINI-TOSI DIRECTION-FINDER (q.v.).

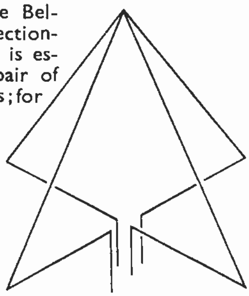


Fig. 22. The Bellini-Tosi direction-finder aerial is essentially a pair of crossed loops; for practical convenience, however, the loops are often triangular.

BELLINI-TOSI DIRECTION-FINDER. Direction-finder using crossed loop-aerials connected to the receiver through a goniometer. The two loops, of a size suited to the intended working frequencies, are normally set at right angles (Fig. 22), and each is connected to one field winding in the goniometer (Fig. 23). Each field winding sets up a magnetic field proportional to the signal strength picked up by the aerial connected to it, and this in turn is proportional to the direction of travel of the passing waves.

If, therefore, the goniometer search coil is rotated to find some measure of the *resultant* maximum or (usually) minimum field, it will provide an indication of the direction in which the waves are crossing the aerials, and

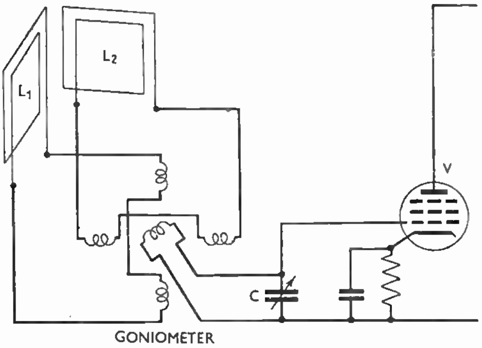


Fig. 23. Elements of a Bellini-Tosi direction-finder. *L*1 and *L*2 are loop aerials fixed at right angles; the goniometer, of four fixed coils and a search coil tuned by *C*, forms the input circuit of the R.F. amplifying valve *V*.

so of the apparent direction of the sender. See RADIOGONIOMETER, SPACED-AERIAL DIRECTION-FINDER.

BETHENOD-LATOUR ALTERNATOR. High-frequency synchronous generator developed in France for use in radio telegraphy. See SYNCHRONOUS GENERATOR.

BEVERAGE AERIAL. Horizontal wire of considerable length but low height (Fig. 24), connected to earth at one end through the receiver and at the other through a resistance or resistance network equal to the line impedance. This aerial has marked directional properties, receiving most strongly from the direction of the end remote from the receiver. Its length is at least comparable with the wavelength being received and preferably equal to several wavelengths. See WAVE AERIAL.

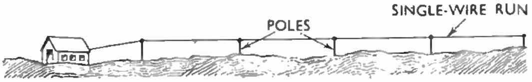


Fig. 24. Essential feature of the Beverage aerial is its great length in proportion to its height. It is commonly run on short poles in the manner of a telegraph line.

BIAS. Direct or steady component of an electrode voltage; the term is not applied to the anode, but is fairly commonly used in connexion with the screen grid and with the control grid and cathode (Fig. 25). In class-A amplification, the grid-cathode potential varies about a steady or direct negative potential, described as "grid bias" and expressed in volts.

The screen-grid potential is usually steady, and does not change with alternating potentials of other electrodes. This steady potential is the screen-grid bias, always positive with respect to cathode.

In some negative-feedback arrangements, however, the screen grid and cathode are connected together by an impedance low to signal frequencies, and their common potential varies at signal frequency.

The screen bias is the steady direct potential difference existing between the screen grid and the cathode. Cathode bias is the steady voltage of the cathode, as distinct from its varying potential when current feedback is used. See ANODE VOLTAGE, AUTOMATIC GRID-BIAS, CATHODE BIAS,

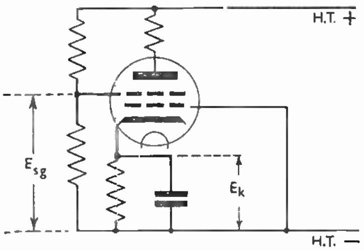


Fig. 25. How positive bias (E_{sg}) may be applied to the screen grid, and negative bias (E_k) to the control grid of a tetrode.

GRID BIAS, GRID POTENTIAL, SCREEN-GRID POTENTIAL.

BIAS DISTORTION. Distortion caused by the spacing or marking elements of signals being lengthened as a result of asymmetry in either the sending or receiving equipment.

BIASED AUTOMATIC GAIN-CONTROL. See DELAYED A.G.C.

BIGRID VALVE. Synonym for DUAL-GRID VALVE.

BILLI-CAPACITOR. Obsolete term describing a form of variable capacitor used in early types of radio equipment. It consisted essentially of two co-axial cylindrical electrodes separated by a tube of solid dielectric, usually ebonite. Adjustment was effected by axial movement of one cylinder with respect to the other so that the area of overlap was changed. It was used with a form of inductor known as a jigger.

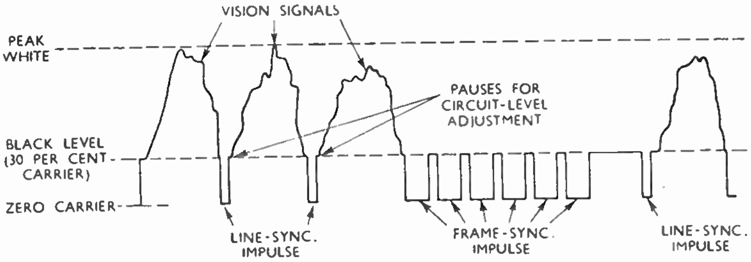


Fig. 26. Wave form of a television signal; the synchronizing impulses occupy, for line, about one-tenth and, for frame, four-tenths of the line duration. After each line-synchronizing impulse there is a slight pause before the signal is transmitted while the carrier black level is adjusted to 30 per cent.

BILLI-CONDENSER. Synonym for BILLI-CAPACITOR.

BIOTRON. Special form of two-stage amplifier in which regeneration is used over a wide range of frequencies. The biotron is not generally used in modern practice.

BLACK AMPLIFIER. Special form of negative-feedback amplifier named after its inventor, and used in line communication.

BLACK LEVEL. Percentage of carrier amplitude corresponding with black in a transmitted television picture. In the case of the Marconi-E.M.I. system of television, it is equal to about 30 per cent of the maximum modulation depth, the high lights increasing the modulation to 100 per cent.

Modulation below 30 per cent (below black level) is often referred to as "blacker" than black, and is that portion of the modulation range which is used for synchronizing impulses. Thus, a decrease of modulation below 30 per cent cannot affect the television screen, which is already dark. Yet, by suitable circuits, any decrease in modulation below this 30 per cent can be used by the receiver to provide synchronizing impulses.

The diagram (Fig. 26) shows the transmitted wave form of the system used. All control of brilliance of the cathode-ray receiver tube is carried out by the portion of the modulation above the black-level line. All the modulation variations below that line are employed for synchronizing purposes, and cannot affect the screen because they merely "increase" the blackness.

BLACK-OUT POINT. Synonym for BLACK LEVEL.

BLACK-OUT VOLTAGE. Bias voltage on the modulator electrode of a valve or cathode-ray tube necessary to reduce the beam current for specified potentials of other electrodes to a negligibly low value. See BLACK LEVEL, CUT-OFF BIAS.

BLANKING. Term given to the process of cutting off the electron beam of a cathode-ray tube during the period when it is returning from the end of one scan to the beginning of the next. Thus, in television, the beam is cut off (by making the grid negative) during the fly-back from the end of each line to the beginning of the next, and from the end of the last line at the completion of a frame to the beginning of the first line to start the next frame.

This blanking is carried out so that the fly-back shall not trace a visible line of light across the screen. Normally, by turning the brilliance control well up, the fly-back can be seen, the blanking potential being overcome by the positive potential applied to the grid of the tube.

BLASTING. Non-linear distortion of a broadcast transmission due to the overloading of microphone, amplifiers, or sender. See NON-LINEAR DISTORTION.

BLATTNERPHONE. Obsolete type of magnetic recorder. See ELECTRICAL RECORDING.

B-LAYER. Ionospheric layer which is thought to exist below the C-layer. Pulse measurements have been obtained which suggest the presence of thin ionospheric layers below the D-layer. The names, C- and B-layer, have been given to two of them. Direct observation of the electrical state of the atmosphere by means of balloons has failed to reveal these ionized layers and their existence is still in doubt. See IONOSPHERE.

BLEEDER RESISTOR. Term used to describe a resistive form of potential divider, when the latter is used to derive a reduced voltage from a high-tension D.C. supply.

BLIND-LANDING SYSTEM. System by which a pilot may land an aircraft in conditions of poor visibility. See LORENZ BLIND-LANDING SYSTEM.

BLIND SPOT. Region where it is not possible to receive an audible signal from a particular sender operating on a specified frequency. Blind spots—often referred to as "dead spaces"—are spaces on the earth's surface between the points where the ionospheric ray is reflected from the earth. As the ray is successively reflected, the blind spots decrease in area and the zones of reception increase correspondingly.

Theoretically, there must always be some signal in the blind spot due to scattering from the ionosphere, but after one or two reflections and the consequent attenuation of the main ionospheric ray, the scattered signal becomes so small as to be below the noise level of the receiver.

Blind spots of a different and localized type also occur at medium, high, and very high frequencies, within the range of the ground ray. They are almost invariably found where the site of the receiver is in a valley, or where forests and high contours lie between the sender and receiver. The intervening contours act as screens and tend to absorb the ground rays. See ABSORPTION, IONOSPHERIC REFLECTION, SKIP DISTANCE.

BLIP. Small "bump" or deflection of the trace on the screen of a cathode-ray tube. This is caused by a pulse, which is sent out from a radar station and is received back at the station after reflection from an obstacle. From the position of the blip in the trace, the distance of the obstacle can be determined.

BLOCKING CAPACITOR. Capacitor used in a circuit to prevent the flow of direct current whilst allowing the passage of alternating current. The value of the capacitance of the blocking capacitor is usually chosen so that the flow of alternating current shall be substantially unaffected by its inclusion in the circuit.

Probably the most familiar form of blocking capacitor is that used to couple the stages of a resistance-capacitance amplifier or prevent the flow of direct current in the load circuit of a cathode follower. The blocking capacitor is also used to prevent direct current from flowing in transformer windings (Fig. 27). See CATHODE FOLLOWER, RESISTANCE-CAPACITANCE AMPLIFIER.

BLOCKING CONDENSER. Synonym for BLOCKING CAPACITOR.

BLOCKING OSCILLATOR. Relaxation oscillator in which the anode current of a valve is periodically blocked by a large negative bias on to the grid. The anode and grid circuits of the valve are tightly coupled magnetically, the grid circuit having a high ratio of inductance to capacitance, and a very high-value grid leak. When oscillation begins, grid current flows in the grid leak and develops across it a bias many times the cut-off value. In this way the anode current of the valve is blocked in less than one cycle, and oscillation ceases. The negative charge on the grid capacitor now leaks away slowly through the grid leak, and after a period the anode circuit becomes conductive again, oscillation starts and the cycle recommences.

If the resonant frequency of the circuit L_1C_1 (Fig. 28) is much greater than that of the relaxation oscillations, a saw-tooth wave form is produced across the grid capacitor; these oscillations can be triggered by synchronizing pulses injected in series with the grid coil. For this reason, blocking oscillators are extensively employed as time bases in television receivers.

BLUE GLOW. Condition when the gas in the bulb of a valve glows with a blue colour. The effect is due to the ionization of the residual gas and may occur in hard-vacuum power-valves. Valves may show a blue glow when about to go "soft." In a soft valve, the effects of ionization produce excessive electrode currents and the valve is useless; but a blue glow may also be seen in a valve which is working satisfactorily, and which may continue to work satisfactorily for a long period. See IONIZATION, GAS-FILLED VALVE, SOFT-VACUUM VALVE.

BOBBIN. Synonym for SPOOL.

BOLOMETER. Form of detector used in measuring output of centimetre-wave apparatus. Basically, it consists of a fine platinum wire enclosed in a vacuum; radio-frequency currents passing through the wire cause its resistance to vary and, by so doing, introduce "unbalance" in one arm of a WHEATSTONE BRIDGE (q.v.).

BOTTOM BEND. Curved portion at the bottom or lower end of a valve characteristic. The term is often used to refer specifically to the bottom portion of the anode-current/grid-

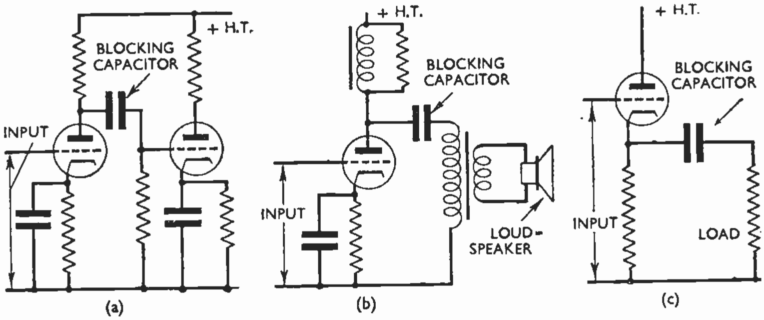


Fig. 27. Three uses of a blocking capacitor: (*a*) in a resistance-capacitance amplifier (in this case it may also be called a coupling capacitor); (*b*) to prevent D.C. from flowing in the transformer windings, while passing A.C., and (*c*) to prevent D.C. from flowing in the load of a cathode follower.

voltage characteristic (see ANODE BEND). It can, however, refer to the curved portion at the foot of any valve characteristic.

BOTTOM-BEND DETECTION. Synonym for ANODE-BEND DETECTION.

BOTTOM-BEND RECTIFICATION. Synonym for ANODE-BEND RECTIFICATION.

BOX BAFFLE. Form of baffle construction for use where space is restricted; for example, the cabinet of a modern radio receiver or loudspeaker. See BAFFLE.

BREAKDOWN VOLTAGE OF GAS. See IONIZATION POTENTIAL.

BREAK IMPULSE. Any transient voltage or current produced by the sudden interruption of a circuit; but more specifically some impulse thus produced and used for signalling purposes, as in some form of automatic telephone system.

BREAK JACK. Jack which has extra contacts arranged to break a circuit when the plug is inserted. See PLUG AND JACK.

BRIDGED T-NETWORK. T-network in which the series impedances are bridged by a fourth impedance (Fig. 29). A lattice network may have an equivalent of a bridged T-network. Null networks are in the form of bridged T-networks; certain forms of bridged T-networks have the property of giving virtually zero attenuation, but change the phase of the waves passing through them. See LATTICE NETWORK, NULL NETWORK, PHASE-CHANGE NETWORK, T-NETWORK.

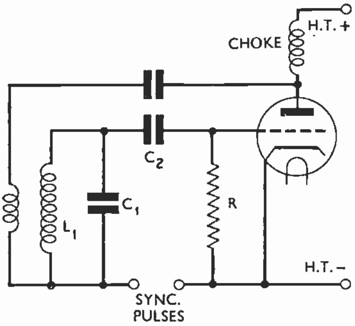


Fig. 28. Blocking oscillator in which C_1 may be the self-capacitance of L_1 or a separate component; C_2 is the grid capacitor across which saw-tooth waves are developed, and R is a grid-leak of very high value.

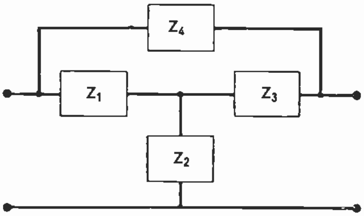


Fig. 29. Bridged T-network; the T-network is formed from impedances Z_1, Z_2 and Z_3, and the bridge by Z_4.

BRIDGE MEGGER TESTER. Resistance-measuring instrument operating on the principle of the Wheatstone bridge. It incorporates a meter and a hand generator. See INSULATION, WHEATSTONE BRIDGE.

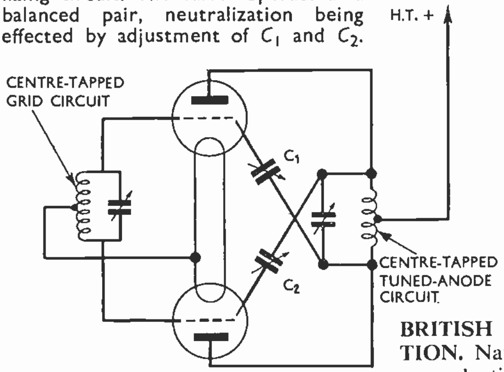
BRIDGE NETWORK. Synonym for LATTICE NETWORK.

BRIDGE NEUTRALIZING. Process of employing an R.F. amplifying circuit in which two valves are connected for balanced operation, the neutralizing voltages being fed from the anode of one to the grid of the other through a suitably small capacitance (Fig. 30). (This is, in effect, negative feedback, and counteracts the positive feedback through the internal capacitance of a triode.)

This method of stabilizing a triode-valve R.F. amplifier is complicated and has been little used in receiver design. Like other neutralizing systems, the bridge method disappeared when the screen-grid valve came into use. The circuit is, however, often employed in high-power senders. See BALANCED VALVE-OPERATION, NEUTRALIZATION.

BRIDGE RECEIVER. Type of radio receiver employing the WHEATSTONE BRIDGE (q.v.) principle, sometimes

Fig. 30. Simple form of bridge neutralizing circuit. The valves operate as a balanced pair, neutralization being effected by adjustment of C_1 and C_2.



used when two-way working is carried on at the same frequency.

BRIDGE-SET. Arrangement of transformers which may be used instead of the hybrid coil when a four-terminal, radio-transmission system is joined to a two-wire telephone system. See HYBRID COIL.

BRIDGE TRANSFORMER. See HYBRID COIL.

BRIDGING AMPLIFIER. Monitoring amplifier of any type which can be bridged across a circuit without drawing any appreciable amount of power therefrom, thereby enabling a broadcast programme, for instance, to be checked without interfering with its passage to the sender.

BRIGHT-EMITTER VALVE. Valve with a filament which glows brightly, in contrast with those having filaments which glow a dull red or those having indirectly heated cathodes which also glow a dull red. The term is obsolescent; in earlier development of the valve, emission was obtained from filaments which worked at much greater temperatures than do modern types. Valves using newer types of filament and indirectly heated cathodes were later introduced and were designated dull-emitter valves. See CATHODE, EMISSION.

BRILLIANCE CONTROL. Operating adjustment of a cathode-ray tube which permits the intensity of the electron beam to be varied. It may be necessary for a brilliance control on a television receiver to be set in conjunction with the contrast control so that good contrast is retained between the black and the white portions of a picture. If the television signals are weak, increasing the brilliance of the picture may appear to cause some reduction of the contrast.

BRITISH STANDARDS INSTITUTION. National organization for the promulgation of British Standard terms, definitions, codes of practice and specifications for materials, articles, etc., and methods of test. The offices of the Institution are in London, and complete sets of British Standards are maintained in Public Libraries and Colleges in several of the principal towns of Great Britain, the British Commonwealth and America.

The definitions of terms given in this encyclopaedia have, in many cases, been based on the British Standard definitions.

BRITISH THERMAL UNIT. Measure of quantity of heat, defined as the amount needed to raise the temperature of 1 lb. of water by 1 deg. F. A more precise definition stipulates that the temperature rise shall be from 60 to 61 deg. F. See CALORIE.

BROADCAST CHANNEL. Channel reserved for, or appertaining to, a broadcasting sender. See CHANNEL.

BROADCAST COVERAGE. See COVERAGE, SERVICE AREA.

BROADCAST EXCHANGE. Synonym for RADIO RELAY SYSTEM.

BROADCASTING. Process of diffusing programmes of information or entertainment by means of electricity, so that such programmes can be heard or seen by use of a receiver. A schematic diagram of a sound-broadcasting system appears at Fig. 31. The programme to be broadcast takes place at what is labelled the programme location. Here the microphone is located; this converts variations of air pressure representing the sounds to be broadcast into variations of electrical potential. Associated with the microphone is the microphone amplifier, which raises the power generated by the microphone to a sufficient level for its transmission over the link between programme location and control room (see MICROPHONE, MICROPHONE AMPLIFIER, RADIO LINK).

The microphone output appears at the control room, and is applied to an amplifier with an adjustable gain control. This raises the output to a level suitable for routing to the sender or senders.

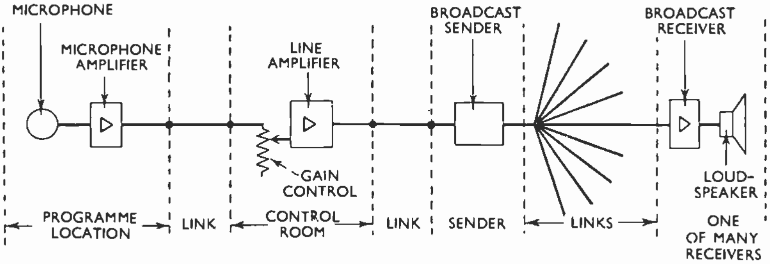


Fig. 31. Schematic diagram showing the essential features that are linked up in a single-programme sound-broadcasting system: programme location, control room, sender, and receiver. The scheme applies also to television broadcasting, except that the microphone is then augmented by a vision pick-up and the loudspeaker by a fluorescent screen on which the moving pictures appear.

The control room is the place in which a team of engineers not only controls the level of the currents which are sent to the various sending stations, but also routes the programmes coming from different programme locations to different senders, so that a minute-to-minute plan for the service as a whole may be obeyed (see CONTROL ROOM, SIMULTANEOUS BROADCASTING).

The control room is linked to the sender so that the controlled level coming from the microphone may be suitably fed into the modulation circuits of the sender equipment.

The sender may be linked to any number of receivers, only one of which is shown at Fig. 31, and these are adjusted by their users to receive the broadcast signals. The receiver energizes a headphone or, more commonly, a loudspeaker, which converts the signals received from the sender into air pressure-waves which reproduce the instantaneous frequency and relative amplitude of the sound waves impinging on the microphone at the programme location (see BROADCAST RECEIVER, HEADPHONE, LOUDSPEAKER).

Obviously, the system shown in Fig. 31 suffices to diffuse only one programme over a limited area; in a normal broadcasting system there are many senders linked together by a telephone network. In principle, the links between the various stages of a broadcasting system may be formed by any sending system such as a radio or transmission line, the latter carrying audio-frequency or modulated carrier-frequency currents. In practice, however, the link between programme location and control room is usually a transmission line—an ordinary telephone line—carrying the audio-frequency currents which comprise the output from the microphone. The output of the microphone is so small, however, that it is considerably amplified first. When it is impossible to use a transmission line to link programme location and control room, a radio link is employed (see TRANSMISSION LINE).

In virtually all circumstances, the link, between sender and the receiver used by the listener, is a radio link. The senders are thus radio-telephone senders. The replacement of this radio link by a wire network has been suggested, but not implemented.

The receivers used by the listening public are primarily designed for use by unskilled persons. The superheterodyne principle is almost always used.

There is an adjustment which makes the receiver sensitive to emissions from the chosen station, and this is called the tuning control; another adjustment, to set the sound intensity at a certain level, is the volume control; and a further adjustment enables senders on long, medium or short waves to be received and tuned-in.

There is no basic technical difference between sound and vision receivers, except that the former has a continuously variable tuning arrangement whereas the latter is frequently designed to work on a fixed frequency. At the sender, the microphone is replaced by a vision pick-up; at the receiver, the loudspeaker is replaced by a screen on which the moving pictures appear.

The enormously wide frequency band containing the waves coming from a vision pick-up makes extreme care necessary when deciding the transmission characteristics of the links joining the various locations. Thus, in the link from studio to the control room, if these are far apart, the transmission line must be equalized, and at every few miles it is necessary to insert repeaters. This is why television studios are usually located close to the television sender. For outside broadcasting, special lines must be used to link the programme location with the studio. The same reasons necessitate the use of a high-frequency carrier wave, and wide band widths. See BROADCAST SENDER, OUTSIDE BROADCASTING, RADIO RELAY SYSTEM.

BROADCASTING STUDIO. Room or auditorium designed for the purpose of rehearsing and performing productions forming the items of broadcast programmes. Broadcasting programmes are composed of a great number of different items. The organization responsible for the programmes equips itself with a building or buildings within which rooms or halls are set aside as studios.

As the programme material may originate from a symphony orchestra or an individual speaker, a great number of different sizes of studio is necessary. But more important is the question of suitable acoustics; the reverberation of an auditorium which is suitable for a large orchestra would be wholly unsuitable, apart from waste of space, for a single speaker. A brass band demands a different acoustical environment from a theatre orchestra; plays and variety shows demand their own special type of studio. Thus there are talks studios, drama studios, and orchestra studios. Apart from broadcasting studios there are the recording and television studios.

In the early days of broadcasting, the microphone and earphones used tended to resonate at frequencies approximating to 1,000 c/s. This gave a reverberation quality to the reproduction, apart from any added acoustic effect of the places where the performances took place. Thus it was necessary to damp studios, that is to say, to make them as little reverberant as possible. Studios in those days held literally thousands of pounds weight of wall-draping, soft carpets, padded ceilings and so on. As the characteristics of transducers improved, so the studios were partly undressed and, as a result of a great deal of acutely conceived and patient work, the modern studio is well adapted to its purpose and gives a pleasant synthesis of the various sounds that are being produced in it.

In dramatic work, movable screens and other devices are used to set up particular acoustical effects which give the listener a sense of varying distances, for instance. The echo room and effects discs also add to the illusion. See ECHO ROOM, STUDIO-CONTROL CUBICLE.

BROADCAST RECEIVER. Receiver designed for domestic use by the public which listens to broadcast programmes. The essential requirements of a broadcast receiver are reliability and simplicity of adjustment, while pleasant appearance is an important commercial attribute. The miniature receiver has found a wide market and, on the whole, the more compact a receiver, consistent with a reasonable performance, the better it pleases a majority taste.

A broadcast receiver is generally classified as a portable, a radio-gramophone, or as a "table" receiver, and may need an external aerial. There is also the sub-division of "mains" and "battery" receivers; the latter, generally portable, is designed for use where there is no mains electricity supply. The "radiogram" is seldom, if ever, battery-operated.

With the exception of miniature receivers and some battery-operated types, the superheterodyne principle of reception is used (see SUPERHETERODYNE RECEIVER). Thus, in typical practice, a frequency-changer precedes a stage of intermediate-frequency amplification; this, in turn, is followed by a detector or demodulator. The detector, usually a diode, feeds its output to the single audio-frequency amplifying valve, commonly a pentode, which energizes the loudspeaker. This is generally a moving-coil type with a permanent magnet, although energized types are still used.

Automatic gain-control is almost universally employed; this is obtained from the output of the intermediate-frequency amplifier by means of a diode detector, and the control voltage delivered by the diode is fed, as grid bias, to the signal-frequency amplifier (if used), the frequency-changer and the intermediate-frequency amplifier, all of which must be variable-mu valves (see AUTOMATIC GAIN-CONTROL, DELAYED AUTOMATIC GAIN-CONTROL). A typical four-valve superheterodyne circuit as used in broadcast receivers is shown in Fig. 32.

A tone-control adjustment may be used to vary the characteristic of a simple equalizer in the audio-frequency circuits. The manual gain-control may be, and usually is, a potential divider in the audio-frequency circuits. Where automatic gain-control is not used, the manual gain-control varies the bias of a variable-mu valve. Push-button tuning is sometimes used and automatic tuning-control by some form of discriminator circuit is employed in the more expensive types of receivers. The receiver is able to pick up signals on the long-, medium- or short-wave bands by the adjustment of an external knob, which puts different inductors into the tuning circuits, the same ganged variable capacitor being used on all wavelength ranges. One of the elements of this capacitor controls the frequency of the local oscillator (see SECOND-CHANNEL INTERFERENCE, TRACKING). To make it easier to tune-in short-wave stations, a so-called "band-spread" circuit is used.

The mains-operated receiver derives power for the anode circuits of the valves from a MAINS UNIT (q.v.) which is mounted on the chassis common to the whole receiver. The smoothing circuit uses electrolytic capacitors of 8–32 μF and an inductor of the order of 20 H. A mains-operated receiver consumes about 50 VA, and has a power factor of about 0·8. The radio-frequency inductors are often of the type having cores of finely divided iron dust and the tuning of the intermediate-frequency circuits may be effected by a mechanical adjustment of the position of such cores (see DUST-CORED INDUCTOR).

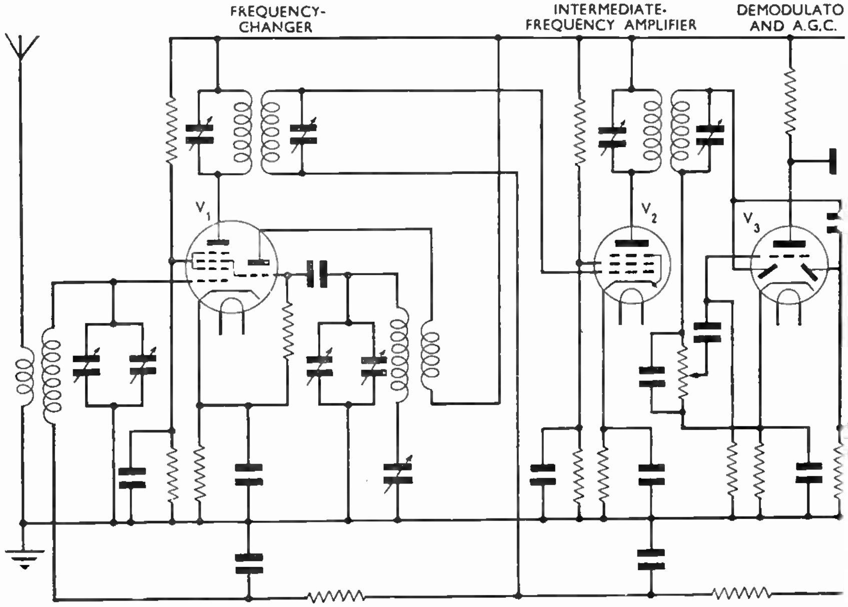
The miniature receiver is commonly formed from one tuned-anode high-frequency amplifier, an R.F. pentode used as an anode-bend detector, and an audio-frequency amplifier. In cheaper receivers only medium- or long- and medium-wave ranges are supplied.

This general description gives a picture of the basic characteristics of many types of receiver, but any one make may embody some or all of the features described. The more expensive types give all the refinements; but the lower the price, the fewer are the refinements offered.

The average receiver gives a flat response up to about 3,000 c/s; a gradual increase of attenuation with increasing frequency is then shown, and few sets give any worthwhile response at frequencies much above 6,000 c/s. The high-fidelity receiver does better and provides variable selectivity, so that better results may be obtained from local senders; while distant reception, at the expense of fidelity, is still possible. See AUTOMATIC TUNING-CONTROL, BAND-PASS FILTER, MAINS UNIT, PORTABLE RECEIVER, PUSH-BUTTON RECEIVER, SELECTIVITY, SMOOTHING CIRCUIT.

BROADCAST RELAY SYSTEM. Synonym for RADIO RELAY SYSTEM.

BROADCAST SENDER. Sender, forming part of a broadcasting system, which sends out modulated waves representing the intelligence being broadcast. All broadcasting systems, as at present constituted, use radio senders to form the link between the place where a programme takes place and the widely scattered listeners who receive the programmes. A broadcast sender is basically a radio-telephone sender. Every precaution is taken to ensure that distortion is reduced to a minimum; thus, if the modulation be sinusoidal, a perfect detector detecting the modulated wave would show the audio-frequency output from it to be virtually constant over a frequency range of from 30 to 10,000 c/s; the harmonic content of the detected wave should, in all conditions,



be negligible; and, therefore, the level of the output from the detector should be strictly proportional to the level of the input to the modulation circuits of the sender up to a modulation factor of 1, which is a modulation percentage of 100 (see MODULATION FACTOR).

Such ideals are not, in fact, realized in practice, while the frequency/modulation-depth characteristic is usually within 1 db. over a frequency range of 30 to 10,000 c/s. The harmonic content of the modulation envelope rises sharply for modulation factors greater than, say, 0·8 to 0·85; thus a modulation factor of 1 would, in many cases, show anything from 5 to 10 per cent harmonic distortion; below 80 per cent modulation, however, it could be less than 1 per cent. These figures apply to typical senders now in use, but more modern types may show improvement. It should be realized that an increase of the modulation depth from 0·8 to 1 produces an increase in detector output of only 2 db., barely detectable to the human ear.

All British and European senders make use of high- or low-power amplitude modulation. In Britain, the older medium-wave senders use low-power modulation. Droitwich uses high-power modulation of the series-valve type (see ANODE MODULATOR, HIGH-POWER MODULATION, LOW-POWER MODULATION). The pre-Second World War Luxembourg sender used out-phasing modulation and claimed a power economy in so doing (see OUT-PHASING MODULATION).

Great care is taken to maintain the carrier-wave frequency of a broadcasting sender at a constant value so that there shall be a minimum sideband interference when senders are employing neighbouring frequency channels.

The necessity to stabilize carrier-wave frequency to avoid interference has resulted in a greater accuracy than is necessary for this purpose alone. Thus the Droitwich carrier is stabilized to one part in 10^7 for long-term stability and can be used as a frequency standard. Short-term stability is of the order of one part in 10^8. See AMPLITUDE MODULATOR, BROADCASTING, DETECTION, SIDEBAND WAVE.

BROADCAST TRANSMISSION ON SHARED CHANNELS. Two or more broadcast senders operating at the same nominal carrier frequency. Such senders are said to share a channel. If the carrier frequencies are not quite equal, receivers in positions where the two carrier waves are received at more or less equal strength produce a "flutter" or whistle depending on whether the difference in frequency is low or high. This spoils reception of both signals.

If one signal is very much stronger than the other the interference caused

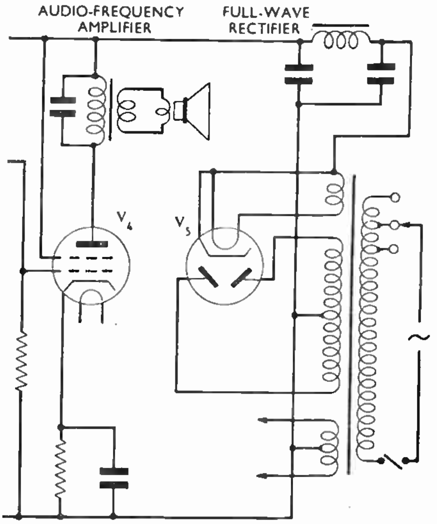


Fig. 32. Superheterodyne receiver for operation from A.C. mains; for clarity only a single wave-band circuit is shown. The circuit is typical of those used in modern broadcast receivers, V_1 being a frequency-changer, V_2 an intermediate-frequency amplifier, V_3 a diode demodulator, V_4 an audio-frequency amplifier, and V_5 a full-wave rectifier.

by the other is much reduced. Thus, if the stations are radiating different programmes there is an area surrounding each sender in which reception of the local programme is clear, but, in between the stations, there will be "mush" areas in which neither programme is heard clearly because of the flutter or whistle. This effect is minimized in practice by international agreement which ensures that senders using shared channels and radiating different programmes are so far apart geographically that the mush area is outside the service area of both the stations.

To give increased coverage, two or more stations of a national broadcasting system are sometimes placed fairly close to each other and radiate the same programme on the same carrier frequency. Such an arrangement produces extensive mush areas unless precautions are taken to keep the carrier frequencies and phases identical.

One way of achieving this result is by the use of a pilot tone which is obtained by frequency division from the carrier wave of one of the stations which is chosen as master. The tone is made low enough in frequency to be sent over telephone line to the other stations, known as slaves, where it is frequency-multiplied to the original value and is used to control the carrier frequencies of the slave stations.

An alternative method of eliminating mush areas caused by two stations radiating the same programme is to set up, in the mush area, a receiver containing a discriminator. The output voltage of the discriminator indicates by its sign whether one received signal is higher or lower than the other. The magnitude of this voltage gives a measure of the frequency difference. This voltage is passed to one of the senders, where it alters the carrier frequency to eliminate the difference in the two carrier frequencies.

BROADCAST TRANSMITTER. Synonym for BROADCAST SENDER.

BROADSIDE ARRAY. Aerial-array so arranged that maximum radiation or most effective reception is in a direction perpendicular to the plane of the array. See AERIAL-ARRAY, CURTAIN ARRAY.

BRUSH DISCHARGE. Phenomenon which occurs when the voltage on some charged body rises to a figure sufficient to cause an incipient breakdown in the insulation of the air which surrounds it, but not sufficient to cause an actual spark or arc. A brush or corona discharge occurs and this usually produces a slight fizzling or hissing sound.

B-SERVICE AREA. Service area in which the field strength is greater than 5 mV/m. See A-SERVICE AREA, SERVICE AREA.

B.Th.U. Abbreviation for BRITISH THERMAL UNIT.

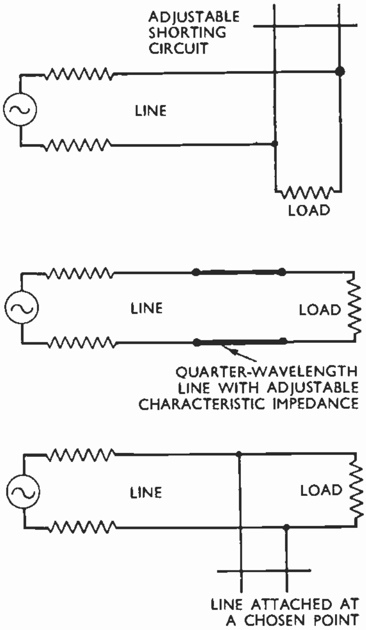


Fig. 33. Three examples of the manner in which a building-out network may be added to a line with the object of matching the load to the line.

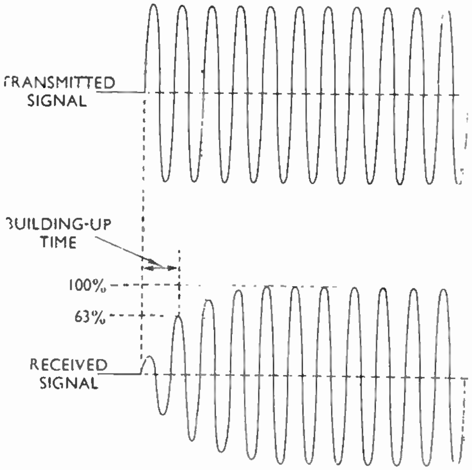


Fig. 34. When a sine wave of constant amplitude is applied to a resonant circuit, the building-up time is taken as that required for the current in the circuit to reach 63 per cent of its steady-state value.

BUFFER CIRCUIT. In radio, the circuit employed in a buffer stage; in electronic organs, the resistance-capacitance unit which controls the rapidity of the rise and fall in the sound waveform envelope.

BUFFER STAGE. Valve stage introduced into an amplifier or oscillator to prevent the characteristics of the earlier stages from being affected by load fluctuations in later stages. It is frequently referred to as separator stage.

BUFFER VALVE. Valve used in a buffer stage.

BUILDING-OUT NETWORK. Network connected to a line so that the impedance of the line is modified. Lines may be used to form the connexion between a generator and a load which is at some distance from the generator; for example, a line is generally used to couple the output of a sender to an aerial.

Maximum power is transferred from a line to its load when the load has an impedance equal to the characteristic impedance of the line. If the load impedance is of such a nature that it does not equal the characteristic impedance of the line, networks may be "built-out" from the line, that is to say, connected to a chosen point on it, so that the load receives the maximum possible power from the line (Fig. 33).

BUILDING-UP TIME. Interval between the time at which the envelope of a transmitted wave is first received and the time when it first reaches a specified fraction of its steady-state magnitude. For example, if a sine wave of constant amplitude is suddenly applied to a resonant circuit, the current in the circuit (or the voltage across it) grows exponentially, as shown in Fig. 34, and, theoretically, never reaches its steady-state value—though, for all practical purposes, it may reach it in a very small fraction of a second. It is usual, therefore, to specify the building-up time as the time that is required for the amplitude to reach approximately 63 per cent of steady-state value. See TIME CONSTANT.

BULB. Airtight container of a valve which encloses the electrode structure and preserves the vacuum or low-pressure gas within. The bulb is usually of glass, but may be of metal. See METAL VALVE, VALVE.

BUNCHER. Electrode and resonant chamber of a valve used for the generation or amplification of centimetric waves. The buncher is arranged so as to cause the electrons flowing between cathode and anode to form into concentrations or "bunches" along the electron stream; these "bunches" arrive at the catcher, which is equivalent to the anode of a valve. See BUNCHING, CATCHER, KLYSTRON, RHUMBATRON.

BUNCHING. Effect when electrons in the electron stream passing between cathode and anode form concentrations, or "bunches." See BUNCHER, KLYSTRON, RHUMBATRON.

BURIED AERIAL. Aerial consisting of a length of insulated cable buried in the ground to a depth of a few feet. Originally claimed to reduce atmospheric interference to a greater extent than the wanted signal, and therefore to give an improved signal-to-noise ratio, the buried aerial is now little used.

BUSBAR. Conductor used to connect a source of electricity supply to several feeders of consuming apparatus. The connexions are invariably made through switches. Low-tension busbars are often of bare copper supported on insulators, but in high-tension systems they are enclosed in an earthed metal casing.

BUSH. Lining for a hole; sometimes called a "bushing." In electrical apparatus, a non-conducting bush is used to insulate a live conductor passing through a metal plate, panel or screen. Insulating bushes are made of ceramics and plastics and of hard or soft rubber.

BUZZER WAVEMETER. Wavemeter in which a resonant circuit is connected across the vibrating contacts of a buzzer to produce oscillations of a given frequency. See WAVEMETER.

BY-PASS. Circuit element, or combination of circuit elements, connected in one part of a circuit to offer a low impedance to certain currents, with the object of preventing these from flowing in another part of the circuit. See BY-PASS CAPACITOR.

BY-PASS CAPACITOR. Capacitor having a reactance which is small compared with a resistance connected in parallel with it. If alternating voltages are applied to the parallel combination, most of the current flows through the capacitor, not through the resistor. A typical use of the by-pass capacitor is in a cathode-bias circuit (Fig. 35). When a wave is applied between control grid and earth, an alternating current is superimposed on the direct current flowing through the valve.

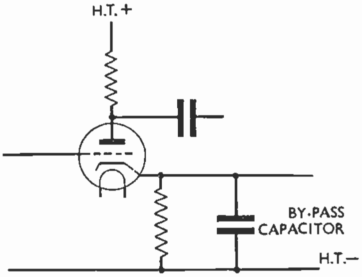


Fig. 35. Example of a by-pass capacitor used to pass the alternating-current component of the cathode current so that it does not flow in the parallel resistor; this current maintains the cathode at a fixed potential.

The by-pass capacitor ensures that the potential of the cathode does not change; to obtain this condition the reactance of the capacitor must be virtually zero at the frequency of alternation of the current flowing from the cathode of the valve. In other words, the alternating component of the cathode current flows through the by-pass capacitor and not through the resistor. If the capacitor has a large capacitance and the frequency of the current alternation is not too low, the voltage drop across the capacitor is nearly zero. See CATHODE BIAS, CURRENT FEEDBACK.

BY-PASS CONDENSER. Synonym for BY-PASS CAPACITOR.

C

C. Abbreviation for COULOMB(s).

CABLE. Special form of conductor containing one or more strands, insulated by a dielectric material from a protective sheathing adapted to the particular purposes for which the cable is intended.

CABOT QUILT. Quilt stuffed with dried eel grass and used in sound studios for producing specific acoustic effects by means of its sound-absorbing qualities.

CADMIUM CELL. Voltaic cell with a remarkably constant e.m.f. and, therefore, commonly used as a voltage standard. The cadmium cell delivers a voltage of 1·0183 volts at a temperature of 20 deg. C., and this figure can be relied upon to an accuracy of one part in a thousand. The cell contains a cadmium anode and a mercury cathode in a cadmium-sulphate solution. Mercury sulphate acts as the de-polarizer.

When intended as a standard of voltage, the cell has a series resistance of several thousands of ohms connected permanently to one of its terminals so that it shall not be damaged by accidental short-circuit. The cell is also known as the Weston cell. See PRIMARY CELL, VOLTAIC CELL.

CAESIUM CELL. Photocell in which the cathode is a very thin layer of caesium deposited on silver. Caesium is more sensitive to light than is any of the other metals (barium, strontium, etc.) that exhibit photo-electric properties, and is, therefore, the most widely used substance in modern photocells. As the caesium cell has increased sensitivity at the red end of the spectrum, it is best suited for use with artificial lighting. See PHOTOCELL.

CAGE AERIAL. Aerial consisting of a number of parallel conductors spaced in cylindrical fashion, and supported by means of hoops (Fig. 1). This type of aerial is characterized by high capacitance and low R.F. resistance. In some instances, the cage construction is applied only to the horizontal span, but in others the down-lead or lead-in is also in cage form.

CALIBRATION. Process of tabulating a set of figures obtained by measuring the performance of an instrument or electrical system, and entering such figures in the appropriate positions on the scale of the instrument, or on a separate graph or chart.

CALORIE. Measure of quantity of heat, defined in metric units. The gramme-calorie is the amount of heat needed to raise the temperature of a gramme of water by 1 deg. C.; a kilogramme-calorie, sometimes called a "large calorie," is 1,000 gramme-calories.

More strictly, the relevant temperatures should be defined; they are always assumed to be 15 and 16 deg. C. except in the case of the "mean calorie," which is determined by finding the amount of heat needed to raise the temperature of a gramme of water from 0 to 100 deg. C., and dividing this by 100 to find the amount per degree over that range. See BRITISH THERMAL UNIT.

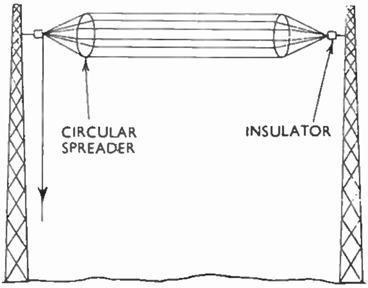


Fig. 1. Cage aerial with single-wire down-lead. The cage construction produces characteristics of high capacitance and low R.F. resistance.

C-AMPLIFIER. Synonym that is sometimes used for LINE AMPLIFIER.

CAPACITANCE. Property of a body which enables it to accept an electric charge, and to hold it subject only to leakage through such insulating arrangements as may be involved. A given amount of charge placed upon a capacitor raises its voltage by an amount which is inversely proportional to the capacitance.

Consider a metal sphere standing on a perfectly insulated pedestal. If the sphere is at the same electrical potential as its surroundings, it is said to be holding zero charge.

Now suppose that, by some means, a large number of extra electrons is placed on the sphere; it will then acquire a negative charge and its potential will differ from that of its surroundings. The extent to which its potential changes when a given quantity of charge is placed upon it is a measure of the capacitance of the sphere. If a large charge is required to produce a certain change of potential, the capacitance is large; if a small charge is sufficient, the capacitance is small. This may be compared with pumping air into a motor tyre; it takes more air to produce a given rise of pressure in a big tyre than in a small one.

The capacitance of an isolated sphere is a simple thing to evaluate; it is just a geometrical function of the surface area of the sphere. However, practical electrical work is not generally concerned with isolated objects in space; capacitances are generally used in circumstances wherein the object is in close proximity to something which profoundly modifies the situation.

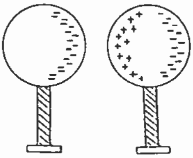


Fig. 2. If a negative charge is placed on one of two metal spheres on insulating stands, it will repel the electrons in the other sphere and so produce a positive-charge condition on the nearer surface.

By way of example, consider what happens when a second metal sphere is placed beside the first (charged) one (Fig. 2). By electrostatic induction, a charge of opposite polarity will be produced on the second, previously neutral, sphere; and this charge will attract the charge on the first sphere. The latter will therefore crowd into that part of the first sphere's surface which is nearest to the second one and the rest of the sphere's surface will thereby be depleted of charge, and will be able to accept some more at the same pressure as before.

In other words, the capacitance of the first sphere will have been increased by the presence of the second; this is a fundamental process in the practical application of the principle of capacitance. When a large capacitance is required for some purpose, it is always obtained by the close juxtaposition of metallic or other conducting surfaces, with some suitable insulating material between them. The capacitance then depends on the area of the metal surfaces facing each other, on the distance between them, and on the nature of the insulating material between. The larger the area and the closer the spacing, the greater is the capacitance. The insulating material affects the capacitance in accordance with its permittivity; the higher its specific permittivity, the greater the capacitance for a given conducting-surface area and spacing (see PERMITTIVITY.)

The evaluation of capacitance calls for a suitable unit, and the obvious basis for a unit is a definition of a standard capacitance in terms of the quantity of charge necessary to raise the potential by one volt; the farad, the basic practical unit of capacitance, is so defined. The farad represents the capacitance of a body whose potential would be raised one volt by one coulomb of electricity. As the farad is too big to be a convenient unit—the earth itself has a capacitance of only about one-seventh of a farad—fractions of a farad, the microfarad (a millionth) and the picofarad (a billionth), are used in practice.

In the experiment with the two metal spheres, a more precise understanding of what happens will result if the electron movements are considered in detail. When the negative charge (which, in fact, is just a quantity of extra electrons) is put on the first sphere, it causes a redistribution of the "loose" electrons in the second sphere; they are repelled by those on the neighbouring sphere, and move away to the opposite side of their own sphere. As they represent a negative charge, the region which they have vacated, being now deficient of electrons, is positively charged and attracts the negative charge of electrons on the first sphere.

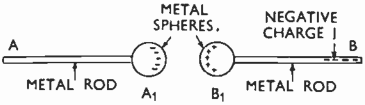


Fig. 3. Negative charge applied at *A* gathers on one side of sphere A_1, and induces a positive charge on the nearer side of sphere B_1 by repelling a corresponding negative charge to *B*.

The negative charge which has been induced in the second sphere, consisting of electrons trying to get as far away as they can from those on the first sphere, will escape altogether if given the chance. If a wire from earth is touched upon the second sphere in the middle of the negative charge, the negative charge will travel down the escape path thus provided, leaving an overall deficiency of electrons on the metal sphere. This phenomenon is more fully discussed elsewhere (see ELECTROSTATICS).

Of more present concern is a less extreme case, in which the escape path is not a complete one, but merely an extension rod attached to the side of the second sphere; with this arrangement, the repelled electrons concentrate at the far end of the rod (Fig. 3).

It is illuminating to follow the sequence of events a little more closely; suppose that there are no charges on the two spheres; a negative charge is inserted at point *A*—the tip of an extension rod fixed to the first sphere. Incoming electrons will then undergo a momentary distribution all over the rod and the sphere; but, as they take up their positions, they begin to repel electrons from the nearer side of the second sphere. These ejected electrons will be sent away down the other extension rod, and will appear as a negative charge at point *B*.

The interesting point is, that a negative charge has been inserted at *A*, and a negative charge has appeared at *B*, just as though there were a through-connexion from one point to the other. Thus the capacitance between the two spheres provides a path for such effects as the sudden application of charges to the system, or even changes in the amount of the charges.

It can now be understood that if an alternating voltage is applied to *A*, something very much like it will appear at point *B*; because the application of an alternating voltage is the same as putting a succession of alternately positive and negative charges into the circuit. In this sense, it is true to say that an alternating current can pass through a capacitance; in effect, it certainly does so; and does so more easily as the capacitance becomes larger and the frequency of alternation higher (see REACTANCE).

The capacitance between two equal parallel surfaces of known area and spacing may be calculated by:

$C = \frac{885A\kappa}{10^{10}d}$, where C is the capacitance in microfarads, A is the area of one surface in square centimetres, κ the permittivity of the material between the plates and d the distance between them in centimetres.

CAPACITIVE. Having the property of capacitance; functioning in a particular manner because of the presence of capacitance. Thus, in A.C. practice, a leading load is sometimes called a capacitive load. See LEADING LOAD.

CAPACITIVE ATTENUATOR. Attenuator, for use at medium and higher radio frequencies, consisting of capacitive elements. See ATTENUATOR.

CAPACITIVE COUPLING. Coupling in which a capacitor is the element common to the two circuits which are coupled. The term is not often used to describe the classic types of filter, in which the shunt arm is a capacitor. Thus a filter composed of series inductors and shunt capacitors is called a low-pass filter, and not a capacitively coupled filter.

CAPACITIVE FEEDBACK. Feedback of energy from one stage of a valve amplifier to another when they are coupled by a capacitance. The coupling may be provided by a capacitor purposely introduced to give feedback, or it may be due to the close proximity of certain components, giving unwanted positive feedback and, possibly, instability.

CAPACITIVE-FEEDBACK OSCILLATOR. Any valve oscillator in which the feedback of energy from the anode to the grid circuit takes place only via a capacitive link, for example, Colpitt's circuit.

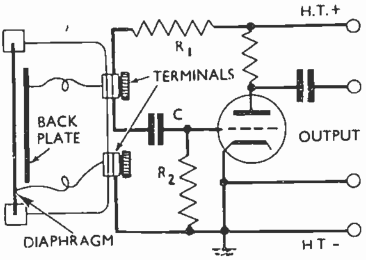


Fig. 4. Diagram of a capacitive microphone showing how the diaphragm and back plate form a capacitor. The alternating e.m.f.s produced at the terminals are amplified by a valve.

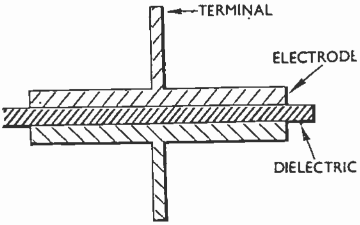


Fig. 5. Essential parts of a capacitor are two conducting electrodes, or plates, separated by a dielectric.

CAPACITIVE LOAD. Synonym for LEADING LOAD.

CAPACITIVE LOUDSPEAKER. Loudspeaker, of which the diaphragm is one electrode of a large capacitor. The capacitor is charged from a D.C. source and the charge is varied by the applied audio signal. This causes the diaphragm to vibrate, producing sound waves at the signal frequency. This type is almost obsolete but a modern balanced type is described under ELECTROSTATIC LOUDSPEAKER in the Appendix. See LOUDSPEAKER.

CAPACITIVE MICROPHONE. Microphone, the diaphragm of which is one electrode of a capacitor. In Fig. 4 the capacitor is formed by the diaphragm and the back plate. The diaphragm is at earth potential and the back plate at about 200 volts above earth. Sound waves impinging on the diaphragm cause it to vibrate, thus varying the capacitance between diaphragm and back plate at the frequency of the sound waves.

The resultant alternating potentials are applied to the grid circuit of the valve via the capacitor *C* and resistor R_2. The resistor R_1, which may be of several megohms, is included to prevent the charge between diaphragm and back plate from leaking away through the source of supply. The advantages of a capacitive microphone are freedom from hiss (characteristic of the carbon microphone) and less susceptibility to blasting. SEE BLASTING, CAPACITANCE, MICROPHONE.

CAPACITIVE PICK-UP. Gramophone pick-up, using the principles of the capacitive microphone, the diaphragm being moved by the needle. This type is not, however, in general use.

CAPACITIVE REACTION. Synonym for CAPACITIVE FEEDBACK.

CAPACITIVE RETROACTION. Synonym for CAPACITIVE FEEDBACK.

CAPACITIVE TUNING. Variation of the resonant frequency of a circuit containing inductance and capacitance by varying the capacitance.

CAPACITOR. Device capable of storing electrostatic energy and having capacitive reactance as its principal property when used in alternating-current circuits. Its essential parts (Fig. 5) are two conducting electrodes closely spaced by a dielectric, or insulating medium. The electrodes usually consist of thin metal plates or foils, or a thin metal coating applied to opposite surfaces of the dielectric. The dielectric may be a vacuum; a gas, such as air; a liquid, such as oil; or a solid, such as mica, plastics film, wax-impregnated paper, or a film formed on the surface of the electrode, or plate, by electro-chemical means.

To make the unit compact, a number of electrodes interleaved with layers of dielectric may be stacked together, with alternate electrodes connected to one terminal and the remainder to the other. This multi-plate, or stacked, technique (Fig. 6) is commonly used when the dielectric is a gas, a liquid, or a rigid solid such as mica.

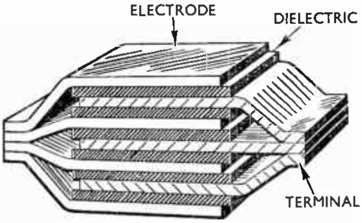


Fig. 6. Multi-plate capacitor showing the method of stacking the electrodes to provide a compact construction.

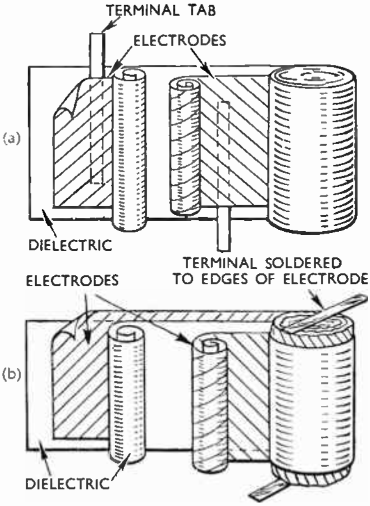


Fig. 7. Two forms of rolled capacitor showing assembly details when (*a*) the electrodes are buried, and (*b*) electrodes are extended or staggered.

With suitable materials, such as paper or plastics film, long strips together with similar strips of metal foil for the electrodes may be wound into a roll. The wound, or rolled, technique (Fig. 7) is much cheaper to produce than the stacked type.

The earliest form of capacitor was a glass jar (see LEYDEN JAR) coated on the inside and outside with metal foil, leaving a clear surface near the rim. It was invented to store electrostatic charges. Volta, the early experimenter, thought that the device had the property of condensing electricity and called it a "condenser," a name which came into general use. Over fifty years ago Kelvin suggested that the name was inappropriate, but it is only recently that it has been superseded by the word "capacitor."

Its property of capacitance C is proportional to the total effective area A of the electrodes, and inversely proportional to the thickness t of the dielectric. It is also proportional to the relative permittivity (dielectric constant) κ and may be expressed, $C \propto \frac{A\kappa}{t}$. If the non-uniformity of the electrostatic field near the edges of the electrodes be disregarded, then we may write $C = \frac{A\kappa}{3{\cdot}6\pi t}$, where A is expressed in square centimetres, t in centimetres and C in micro-micro-farads.

In the stacked construction, $A = na$, where n is the total number of layers of dielectric (one less than the number of conducting plates), and a is the overlapping area of one pair of plates.

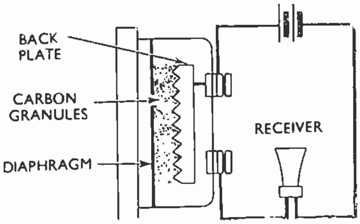


Fig. 8. In the carbon microphone, sound waves impinging on the diaphragm cause variation in the contact resistance of the carbon granules, producing variations in current in the external circuit which includes a receiver.

In the rolled construction, $A = (2m-1)\pi dw$, where m is the number of turns of each electrode (assumed equal), d is the mean diameter of the winding and w is the overlapping width of the electrodes (both in centimetres).

The volume υ of dielectric material per unit capacitance is $\frac{At}{C}$, so that if $C \propto \frac{A\kappa}{t}$, then $\upsilon \propto \frac{t^2}{\kappa}$. Also, if V is the safe working voltage of the capacitor and ε is the safe electric stress in the dielectric in volts per centimetre, then $t \propto \frac{V}{\varepsilon}$ and $\upsilon \propto \frac{V^2}{\kappa\varepsilon^2}$.

The size of a capacitor is not only of interest to the user from considerations of space, but also because size usually bears a close relationship to cost. The last equation given above is, therefore, of great interest to the designer and user. It shows firstly that, per unit capacitance, the size of a capacitor is proportional to the square of the working voltage, and secondly that it is inversely proportional to two properties of the dielectric: the relative permittivity and the electric strength. The latter property is the more important because it appears as a squared term.

For many materials the value of ε increases as the thickness decreases. Thus for impregnated paper about 0·03 mm. thick it may reach a value of 200 kV per mm., and for polystyrene films of the same thickness figures as high as 500 kV per mm. have been observed.

In D.C. circuits, another important property of the dielectric is its volume resistivity which determines the insulation resistance. If ρ is the volume resistivity in ohms per cm. per cm.^{2}, then the insulation resistance R is equal to $\frac{\rho t}{A}$ which, by substitution from $C \propto \frac{A\kappa}{t}$, may be written $R \propto \frac{\rho\kappa}{C}$. The insulation resistance per unit capacitance is therefore $\rho\kappa$.

For small values of capacitance, leakage over the surface of the dielectric at the edges becomes more important than that through the dielectric, but it does not lend itself to a simple formula.

In A.C. circuits, an important property of the dielectric is its power factor, to which is related the dielectric losses. At very high frequencies, this and the residual inductance of the electrodes and terminals are most important properties. If the power factor is $\cos\varphi$, the equivalent shunt resistance across the capacitor is $\frac{1}{2\pi fC\cos\varphi}$, and the power loss at a working voltage V is $2\pi fC\,V^2\cos\varphi$. Since C is proportional to $\frac{A\kappa}{t}$ and $V = t\varepsilon$, the power loss may be written: $P \propto 2\pi fA\kappa\, t\varepsilon^2\cos\varphi$, and

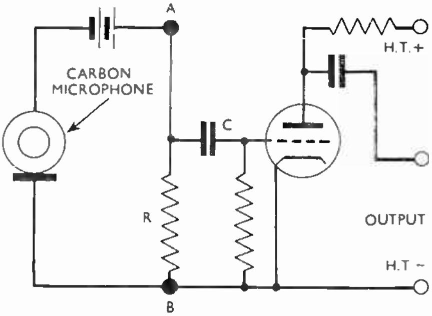


Fig. 9. Varying currents produced by sound waves on the diaphragm of the microphone are applied through a resistor *R*; corresponding alternating e.m.f.s are produced across *R* and are amplified by the triode.

the power loss per unit volume: $p \propto 2\pi f \varkappa \varepsilon^2 \cos \varphi$.

In general, therefore, it is necessary, at high frequencies, to reduce the working voltage in inverse proportion to the square root of the frequency. Thus a capacitor rated at 1,000 volts at 1 Mc/s should be run at no more than 100 volts at 100 Mc/s if the dissipation is to remain approximately the same. For a given working voltage, the product $\varkappa \cos \varphi$ (sometimes called the loss factor) is a good indication of the quality of a dielectric for use at high frequencies. See CAPACITANCE, DIELECTRIC LOSS, FIXED CAPACITOR, VARIABLE CAPACITOR.

CAPACITY. See CAPACITANCE, CAPACITIVE.

CARBON MICROPHONE. Microphone working on the principle that the resistance of closely packed carbon granules varies under varying pressure. In Fig. 8 sound waves impinging on the diaphragm cause pressure variations to be exerted upon the carbon granules inserted between electrodes formed by the diaphragm and the back plate. A D.C. potential applied to the electrodes produces a current in the external circuit incorporating a receiver.

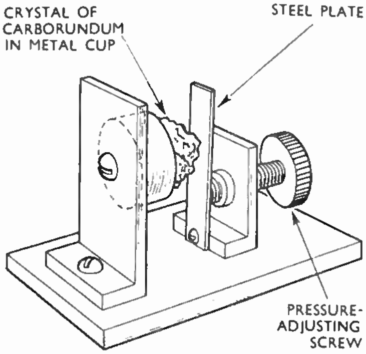


Fig. 10. In the carborundum detector a steel plate is held with fairly heavy pressure against a carborundum crystal secured in its cup by Wood's metal.

As the diaphragm vibrates at speech frequency, the contact resistance of the granules between the electrodes varies at the frequency of the diaphragm vibration. Therefore, the current through the receiver will rise and fall about a mean value, causing the receiver diaphragm to vibrate at the frequency of the microphone diaphragm. These principles are applied to the telephone.

When applied to radio broadcasting, the varying currents through the resistor *R* (Fig. 9) produce alternating e.m.f.s at the terminals *A* and *B* to which an amplifier is connected, the capacitor *C* preventing the D.C. potentials from reaching the amplifier. See MICROPHONE.

CARBON PICK-UP. Gramophone pick-up working on the principles of a carbon microphone. It is not in general use.

CARBORUNDUM CRYSTAL. Crystal of silicon-carbide used for detection of radio signals. See CARBORUNDUM DETECTOR.

CARBORUNDUM DETECTOR. Device for detecting radio-frequency signals; it consists of a carborundum crystal in contact with a steel plate,

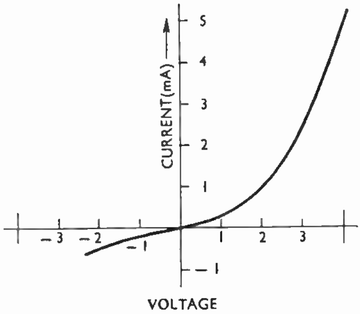


Fig. 11. Operating characteristic o a carborundum detector; best results are obtained when a small positive potential is applied, as in Fig. 12.

as shown in Fig. 10. Such a combination passes current more readily in one direction than in the other direction, and is therefore suitable for producing rectification. The carborundum detector has the advantage that a fairly heavy pressure is required between the steel plate and the crystal; hence it is not liable to be affected by mechanical vibration and it is thus stable in operation.

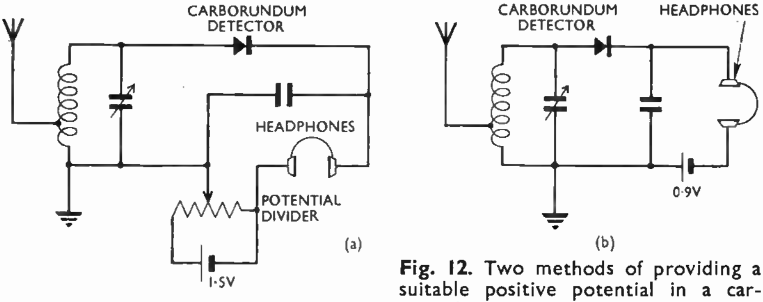


Fig. 12. Two methods of providing a suitable positive potential in a carborundum-detector circuit.

For optimum results a small positive potential is necessary, as will be seen from Fig. 11. To meet this requirement, the circuits of Figs. 12a and 12b are used. In the first, a potential divider is incorporated across a normal dry cell of $1\frac{1}{2}$ volts e.m.f., and the slider adjusted until the most sensitive condition is obtained. The second arrangement uses a special cell of 0·9 volt, this being approximately the voltage that is required to bring the crystal to its most sensitive condition.

CARBORUNDUM RECTIFIER. See CARBORUNDUM DETECTOR.

CARDIOID DIAGRAM. Heart-shaped polar diagram obtained by combining the output of a loop- or frame-aerial with that of a simple vertical aerial. The diagram so obtained is of use in determining the "sense" of a bearing taken with direction-finding equipment (Fig. 14). See CARDIOID RECEPTION, DIRECTION-FINDING, POLAR DIAGRAM.

CARDIOID RECEPTION. Method of reception used in direction-finding whereby a loop-aerial is used in conjunction with a vertical aerial to produce a heart-shaped polar diagram capable of determining a bearing with "sense." The word "cardioid" is of Greek derivation and means heart-shaped.

The simplest form of direction-finder is a vertical loop-aerial capable of rotation about a vertical axis. On rotation of the coil, maximum signal strength is obtained when the plane of the loop points towards the sender, and minimum signal is heard when the plane of the loop is at right angles to the sender.

The polar diagram of the loop has the shape of the figure eight. The change of signal strength is much more

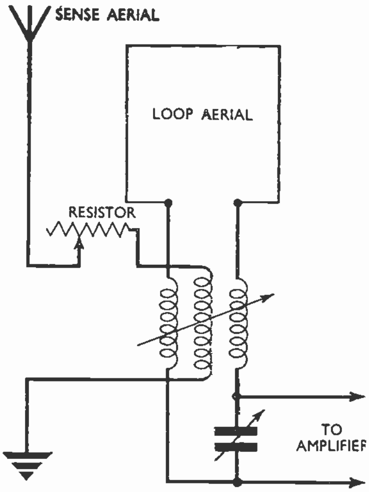


Fig. 13. Circuit by means of which a cardioid diagram is obtained. The resistor is adjusted so that the e.m.f. due to the sense aerial is made equal to that of the loop-aerial.

pronounced when minimum signals are being received than when maximum signal strength is obtained. Thus it is possible to determine a bearing more accurately from the zero-signal position, and in practice the zero-signal position is always used.

Unfortunately, there are two positions of the loop which will give zero signal, and the bearing taken may be not a true, but a reciprocal bearing. It is therefore necessary to find some means of determining which of the two bearings is the correct one; in other words, the correct sense must be determined.

To do this, both a loop-aerial and a simple vertical aerial are used; the polar diagram of the loop-aerial is in the shape of the figure eight, whilst that of the vertical aerial is circular, as it receives equally well in all directions.

In a sense-finding system, use is made of the maximum-signal-strength position of the loop diagram; for although the loop has two "maximum" positions, the current flow round the loop must be in opposite directions in the two positions as the side which formerly received the wave first now receives it last.

By coupling the loop-aerial and the vertical aerial to a second circuit, the loop voltages will add to the aerial voltages in one maximum position and will oppose them in the other. To obtain correct phase relationships in the second circuit, that is, to have the loop e.m.f. in phase or 180 deg. out of phase with the e.m.f. from the vertical aerial, an alteration in phase by 90 deg. of one e.m.f. relative to the other must be brought about.

This is achieved by inductively coupling the loop to the vertical aerial. Fig. 13 illustrates a typical circuit. The resultant polar diagram now becomes a combination of the loop- and vertical-aerial diagrams and may be obtained by adding the two vectorially. The diagram so obtained is a heart-shaped figure (Fig. 14), whose zero-signal point occurs when the loop is pointed towards the sender.

The zero of the cardioid is at 90 deg. from either of the zeros obtained with the loop alone, and, providing the

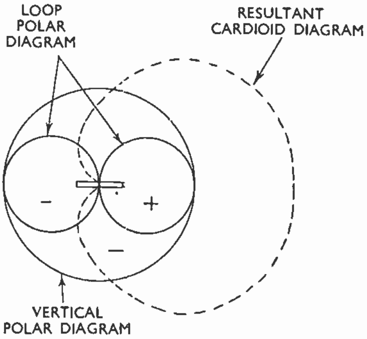


Fig. 14. Cardioid diagram representing the effect of coupling a short vertical aerial of correct size to a loop-aerial. There is now only one maximum and one minimum condition, both in line with the direction of the loop. The vertical aerial is normally switched in only to determine sense.

cardioid is perfect in shape, it may be used directly to take sensed bearings. But in practice the cardioid is rarely efficient for this purpose, and the loop alone is generally used to obtain a bearing, the cardioid being switched in only to determine the sense.

It is important to ensure that the e.m.f. at the amplifier due to the vertical aerial is exactly equal to that due to the loop, otherwise distortion of the cardioid results. If the loop e.m.f. is too small, zero-signal point is very flat; if it is too large, several zeros may appear.

To obtain this necessary equality of e.m.f.s a small, variable resistor is usually included in series with the vertical aerial and adjusted as required. The resistor also serves to maintain the correct phase relationships between aerial and loop. See DIRECTION-FINDING, LOOP DIRECTION-FINDER.

CARRIER. Carrier-wave transmission system for signalling over physical circuits; for example, carrier-wave transmission through telephone lines. The term is also used as an abbreviation for CARRIER WAVE (q.v.).

CARRIER AND DOUBLE-SIDEBAND SYSTEM. Amplitude-modulated transmission in which the carrier and all the sideband waves are radiated.

CARRIER AND SINGLE-SIDEBAND SYSTEM. Amplitude-modulated transmission in which the modulated wave contains the carrier wave and either the upper or lower sideband waves. The other sideband waves are eliminated by a filter. See SINGLE-SIDEBAND MODULATION.

CARRIER FREQUENCY. Frequency of the carrier wave. See CARRIER WAVE, CARRIER-WAVE TRANSMISSION.

CARRIER TELEGRAPHY. Telegraphic code transmission utilizing the modulation (generally at audio-frequencies) of a radio-frequency carrier current.

CARRIER TELEPHONY. Transmission of speech frequencies utilizing the modulation of a radio-frequency carrier current.

CARRIER TERMINALS. Terminals of a modulator to which the carrier wave is applied to be modulated See MODULATOR.

CARRIER WAVE. Wave, in any modulation system, some characteristic of which is varied by the modulating wave. There are three waves in a modulation system; the wave of which some characteristic, such as amplitude, frequency, phase or duration, is changed; second, the wave which alters a characteristic of the carrier wave; and third, the wave resulting from modulation. In a carrier-wave transmission system, one of the characteristics of the carrier wave is changed by the modulating wave.

The modulated wave usually contains a component with the same frequency as that which, in the process of modulation, had its characteristic altered by the modulating wave, and this also is called the carrier wave. In amplitude modulation, the carrier wave in the modulated wave has a constant amplitude, and is accompanied by sideband waves (see AMPLITUDE MODULATION). In suppressed-carrier modulation, the carrier wave in the modulated wave is suppressed. In frequency and phase modulation, the carrier wave appears in the modulated wave, but its amplitude may differ according to the nature of the modulating wave and may even be zero (see FREQUENCY MODULATION, PHASE MODULATION, SIDEBAND).

In frequency-changing, the wave applied to the carrier terminals of a modulator is sometimes called the carrier wave. See CARRIER, CARRIER-WAVE TRANSMISSION, COMMUTATION MODULATION, MODULATION, PULSE MODULATION.

CARRIER-WAVE TRANSMISSION. Electrical transmission utilizing modulation of a single-frequency carrier current.

CASCADE CONNEXION. Circuit connexion in which the output from one circuit element or circuit elements forms the input to another similar circuit element or group of circuit elements. An amplifier is formed by the cascade connexion of valve stages, the output from one valve forming the input to the next.

In filters with several sections, there may be said to be a cascade connexion of sections, since the output from one section forms the input to the next.

In a ladder network there is a cascade connexion of similarly related groups of circuit elements, each comprising a section. See AMPLIFIER, FILTER, LADDER NETWORK.

CATCHER. Electrode and resonant chamber of a valve used for the generation and amplification of centimetric waves. It is equivalent to the anode in a class-C amplifier. The electrons arrive in bunches, cause pulses of current to reach the catcher, and set up resonating currents in it. See BUNCHER, BUNCHING, KLYSTRON, RHUMBATRON.

CATHETRON. American name for a valve in which the control grid is external to the bulb and so arranged that changes of potential on the grid tend to influence the flow of current between other electrodes within the bulb.

Claims have been made, from time to time, that it is possible to control the flow of current by means of a grid which, while it produces a field within a valve, is nevertheless situated outside the valve. A soft valve would be essential; in a hard valve with a glass bulb the electrons would collect on the glass and form a space charge which would not be altered by the grid potential. Apparently, not a great deal of success has been achieved, and so the cathetron has not been used in practice.

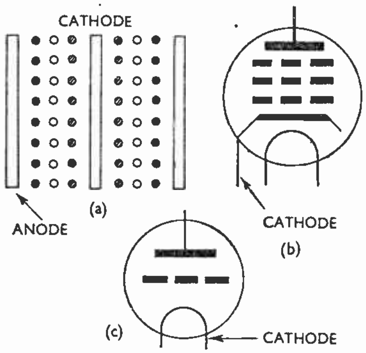


Fig. 15. Cross-section of electrodes in a pentode (*a*), showing the cathode at the centre. Diagrammatic representations are: (*b*) indirectly heated cathode and (*c*) filament cathode in a triode.

CATHODE. Electrode, of a glow-tube, tube, or valve, which is held at a negative potential with respect to the anode. The cathode of a valve, cathode-ray tube or X-ray tube is the electrode which emits electrons. This definition brings out the point that in a glow-tube, in which the conduction of electricity between anode and cathode is due to the ionization of a gas, the cathode does not emit primary electrons as it does in valves and tubes (see GLOW-TUBE, IONIZATION).

The cathode of a valve or tube may be in the form of a wire which is heated or it may be a metal tube, coated with certain metallic oxides, which is heated by a separate heater (Fig. 15b). In the former case, the cathode is known as a "filament"; in the latter, it is called an "indirectly heated cathode." In both these cases, the heating of a substance causes it to emit electrons which form in a cloud around the cathode and conduct electricity between cathode and anode, or between cathode and other electrodes.

The life of a valve depends upon how long the cathode continues to emit electrons. The cathode in a gas-filled valve may be destroyed by ion-bombardment if the voltage drop exceeds a certain value. In valves handling large power, the anode voltage is tens of thousands of volts and the residual gas may contain ions which fall on to the cathode at enormous velocity. This makes it necessary to use filament-type cathodes made of pure tungsten in such valves, as any coating on the filament would be destroyed. See EMISSION, FILAMENT, GAS-FILLED VALVE, INDIRECTLY HEATED CATHODE, VALVE.

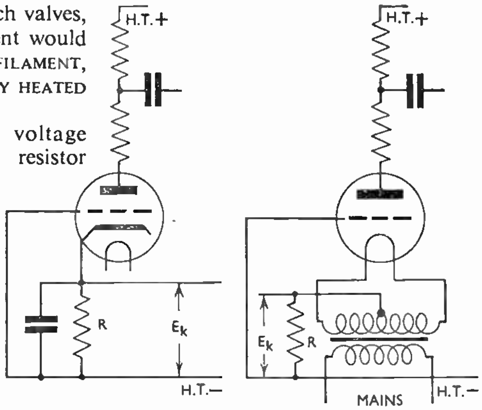


Fig. 16. Provision of cathode bias when the cathode is (*left*) indirectly heated and (*right*) a filament. The correct value of cathode resistor *R* is obtained by dividing the required grid-bias voltage E_k by the cathode current that flows with that value of bias.

CATHODE BIAS. Bias voltage obtained by connecting a resistor between cathode and the negative terminal of the high-tension supply. The grid-cathode potential in many forms of amplifier must be such that the grid is negative with respect to the cathode. Before the introduction of the indirectly heated cathode, it was common to connect one side of the filament to earth and to apply a negative potential to the grid.

With the indirectly heated cathode it is possible to earth the grid so far as bias potential is concerned, and make the cathode positive. This is conveniently done, as shown in Fig. 16, by causing the cathode current to pass through a resistor, thus making the non-earthy end positive with respect to earth. The great advantage of the indirectly heated cathode is that the valves in an amplifier may be given different values of cathode bias and yet be supplied by heater power from a common source.

When filament-type valves are to be given cathode bias, the second arrangement shown in Fig. 16 is used; if several valves require different values of cathode bias, each must have a separate transformer.

So far as steady bias potential is concerned, it makes no difference whether the cathode-bias resistor is shunted by a capacitor or not. But where the alternating potential of the cathode is concerned, the capacitor may have a profound effect; when it is connected, there is no negative-current feedback; when it is not connected, negative-current feedback occurs. See AMPLIFIER, AUTOMATIC GRID-BIAS, CURRENT FEEDBACK, FILAMENT, GRID BIAS, INDIRECTLY HEATED CATHODE.

CATHODE-BIAS RESISTOR. Resistor in cathode-bias circuits which maintains the cathode at a positive bias with respect to the grid. See CATHODE BIAS.

CATHODE COUPLING. Form of interstage connexion in a valve amplifier, in which the output from the stage is taken from the cathode. Thus a cathode-coupled amplifier comprises a number of cathode-follower ampli-

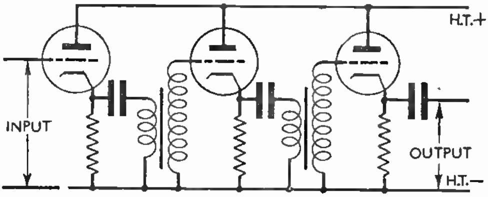


Fig. 17. Amplifier using cathode coupling. Although the transformers step up the voltage the circuit is that of a power amplifier.

fiers in cascade (Fig. 17). It should be noted that a cathode follower is not a voltage amplifier, although power is amplified; but it is possible to include transformers in such an amplifier to obtain a voltage gain. See CATHODE FOLLOWER.

CATHODE CURRENT. Total current flowing to and from the cathode electrode. No distinction is made between the steady and alternating components of the cathode current, such as that made concerning anode current (see ANODE CURRENT, ANODE-FEED CURRENT). The steady component of the cathode current is greater than the anode-feed current by the amount of other electrode currents, such as screen current and suppressor-grid current.

The control-grid current, when the control grid is positive with respect to cathode, must also be added to the cathode current. Thus the cathode current is essentially the total space current. See GRID CURRENT, SCREEN-GRID CURRENT, SPACE CURRENT.

CATHODE EFFICIENCY. Number expressing the milliamperes of emission per watt of power used in heating the cathode. The table below gives the cathode efficiency in terms of various materials used in cathodes of valves.

Tungsten and thoriated tungsten are used for filaments, oxide-coated materials for indirectly heated cathodes.

Tungsten filaments, in spite of their lower efficiency, are used because they alone are robust enough to withstand positive ion bombardment when the anode volts are of the order of 6–10 kV. That such voltages must be used when the anode dissipation is in the tens-of-kilowatts range is obvious, for lower voltages would require larger anode-feed currents, and hence greater emission, which would in turn imply more filament power. See EMISSION, FILAMENT, INDIRECTLY HEATED CATHODE, WORK FUNCTION.

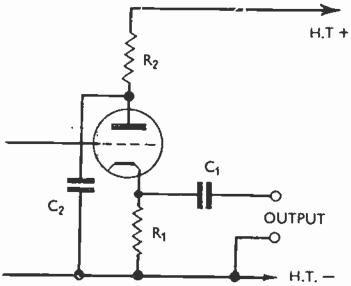


Fig. 18. Simple cathode-follower circuit in which the coupling components are resistor R_1 and capacitor C_1.

CATHODE FOLLOWER. Valve whose output is delivered from the cathode instead of from the anode circuit. Fig. 18 illustrates a typical cathode-follower circuit with a coupling resistance in series between cathode and earth; the coupling components are R_1 and C_1, the latter being the equivalent of the grid capacitor in a normal resistance-capacitance coupling; R_2 and C_2 are merely the decoupling components.

The special characteristics of the cathode follower are these: (1) its output voltage is in phase with that of the input, unlike the normal amplifying valve with output taken from the anode, where the voltages

Type of Emitter	*Normal Operating Temperature (deg. K.)*	*Cathode Efficiency (milliampères per watt of heating power)*
Tungsten	2,450–2,600	3–15
Thoriated Tungsten ..	1,900	62·5
Oxide-coated Materials ..	1,100–1,700	50–125

are in opposite phase; (2) the cathode follower gives no voltage gain but considerable negative feedback, and (3) its output impedance is low. These features make the cathode follower valuable for various special tasks, as in television circuits, passing signals into a low-impedance load such as a transmission line without a matching transformer, and the like.

CATHODE MODULATION. Amplitude modulation in which the modulating wave is applied to the cathode circuit of the modulated amplifier. The circuit (Fig. 19) may be regarded as a combination of a GRID MODULATOR (q.v.) and an ANODE MODULATOR (q.v.). When the modulating-wave voltage increases, the grid/cathode potential becomes more negative and the anode current is reduced; moreover the anode/cathode potential also is decreased, and this tends to decrease the anode current. Conversely, when the modulating-wave voltage decreases, the anode current rises. Thus the gain of the modulated amplifier varies in accordance with the form of the modulating wave, and the output of the modulating amplifier is an amplitude-modulated wave.

Cathode modulation is better than grid modulation and has the same advantage of economy in modulating-wave power; but the quality is inferior to that of anode modulation.

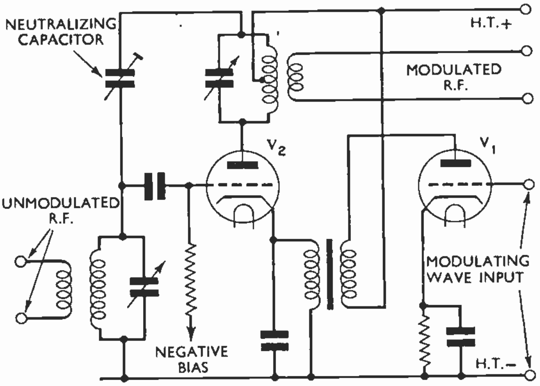


Fig. 19. Cathode-modulation circuit in which V_1 is the modulator valve and V_2 the modulated amplifier. The arrangement may be regarded as a combination of grid modulator and anode modulator.

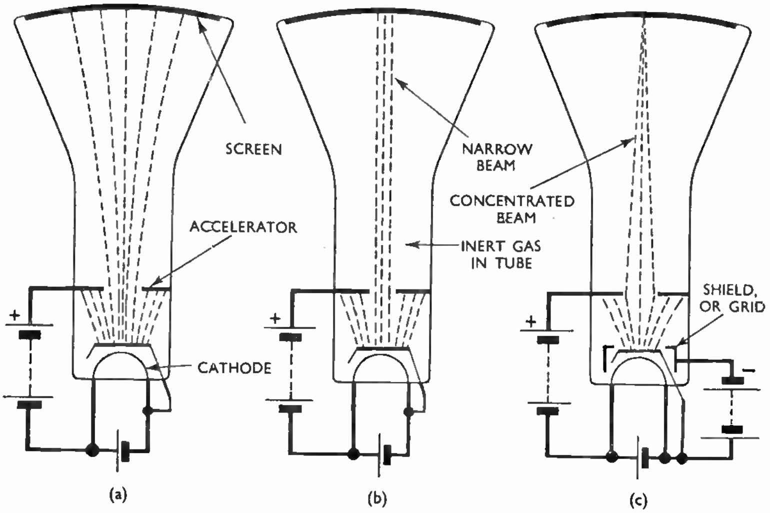
CATHODE POTENTIAL. Difference of potential between the cathode electrode and earth. A positive bias voltage on the cathode when the grid is earthed produces the same conditions as when the cathode is earthed and a negative bias is applied to the grid. See CATHODE BIAS.

CATHODE-RAY DIRECTION-FINDER. Direction-finder in which the bearing of the distant sender is displayed directly on the screen of a cathode-ray tube. In its basic form, such a direction-finder receives signals from a pair of directional aerials at right angles and applies them to the X and Y plates of the tube. If care is taken to ensure that the signals remain in phase, the spot traces out a line which is the resultant of the two applied forces, and is in fact at an angle equivalent to the required bearing. See CATHODE-RAY TUBE.

CATHODE-RAY OSCILLOGRAPH. See OSCILLOGRAPH.

CATHODE-RAY OSCILLOSCOPE. See OSCILLOSCOPE.

CATHODE-RAY TUBE. Vacuum tube used extensively in industry and science for the investigation of mechanical, electrical and biological problems (see OSCILLOGRAPH). A beam of electrons from the cathode is focused on a screen inside the tube, and the point of the beam traces the wave form of the phenomenon being examined. The cathode-ray tube also plays an important part in television reception and in the application of radar.



(a) (b) (c)

Fig. 20. Principles of electron emission in a cathode-ray tube; (*a*) a proportion of the electrons passes through the aperture in the positively charged accelerator to impinge on the fluorescent screen. In a soft-vacuum tube focusing is achieved (*b*) by the release of positive ions from an inert gas, and (*c*) by the additional effect of a negatively charged shield which surrounds the cathode.

In construction and operation, the cathode-ray tube resembles a multi-electrode valve. The cathode, when heated, emits electrons which are attracted to a positively charged anode or accelerator (Fig. 20a). A number of electrons pass through an aperture in the accelerator to the envelope of the tube.

If the accelerator potential is increased, more electrons pass through the aperture, and their velocity is increased. By coating the inside of the tube with a substance such as zinc sulphide, a screen is formed which becomes fluorescent when electrons fall upon it (see FLUORESCENT SCREEN).

If an inert gas, for example, argon, is introduced into the evacuated tube (see SOFT-VACUUM VALVE), the bombardment of the gas molecules by the electrons releases positive ions. These are reluctant to leave the central path of the beam and, by virtue of their positive charge, attract those electrons which spread out fan-wise from

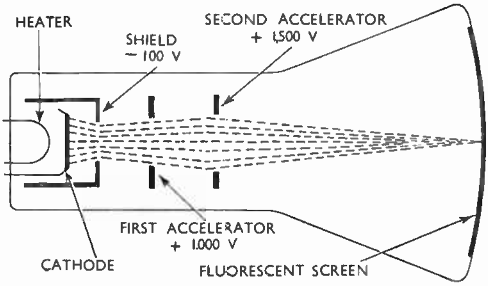


Fig. 21. Fundamentals of an indirectly heated hard-vacuum cathode-ray tube. Electron emission is controlled by varying shield voltage; focusing is effected by varying the positive voltage on one of the two accelerators.

the centre. The effect is to concentrate the electrons into a narrow beam (Fig. 20b), thus increasing the brilliance of the glow on the screen.

The concentration of the beam can be increased by surrounding the cathode with a negatively charged shield (Fig. 20c), the effect of which is to bend the rays inwards, producing a pencil of light on the screen. If the shield potential is adjustable, it has the additional function of controlling the intensity of the beam; if the negative potential is increased sufficiently, the beam can be extinguished entirely (see GRID BIAS).

A soft, or low-vacuum, tube produces a brilliant image for a relatively low accelerator voltage (50–500 volts), but it has a short life because the ionized gas causes deterioration of the cathode.

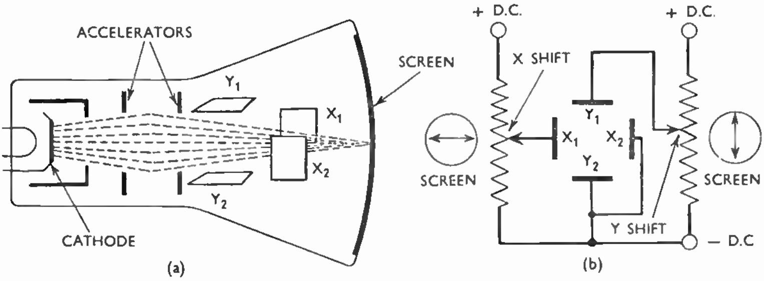


Fig. 22. Movement of the point of the beam over the screen of a cathode-ray tube is effected by two pairs of deflector plates (*a*). Adjustment of X-shift control (*b*) causes horizontal deflection, and of Y-shift control vertical deflection.

Another method of focusing is by using two or more accelerators, these having positive potentials of different values (Fig. 21). The electric fields created around these accelerators have the effect of bending the rays inwards, causing them to strike the screen at a focal point.

A stationary spot of light on a screen serves no useful purpose. If, however, it is deflected over the surface of the screen, it traces the wave form of the deflecting forces just as a recording thermometer traces the variations in temperature on a chart.

If two pairs of deflecting plates are placed in the path of the beam (Fig. 22a) the point of the beam can be deflected over the surface of the screen by varying the potentials applied to the plates (see DEFLECTOR PLATES). A voltage applied to the X plates causes horizontal deflection. If the Y plates are placed in a plane at right angles to that of the X plates, the Y plates cause vertical deflection.

When investigating a wave form, it is desirable for the initial operating point of the beam to be concentrated in the centre of the screen. This can be effected by connecting a source of D.C. potential to the plates as shown in Fig. 22b. The potential-divider controls are called the X shift and Y shift respectively. Varying the X shift causes the beam to move to the right or left; varying the Y shift causes it to move up or down.

The voltage to be examined is normally connected to the Y plates. Assuming no external voltage on the X plates (other than the X-shift voltage), an A.C. voltage having a frequency above about 10 c/s produces a vertical trace on the screen (Fig. 23), the length of the trace being proportional to the deflecting voltage. Such a trace indicates amplitude and not the wave form of the external voltage.

To examine a wave form, it is

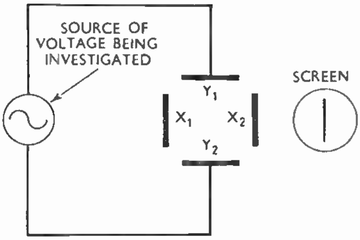


Fig. 23. A vertical trace is produced on the screen of a C.R.T. with an alternating voltage on Y plates and no alternating voltage on X plates.

necessary to indicate how the vertical movement varies with respect to time. For this purpose, a time-base voltage is applied to the X plates; the time-base voltage has a saw-tooth wave form (see RELAXATION OSCILLATOR). The effect of applying such a voltage to the X plates is to cause the beam to be deflected horizontally at comparatively low velocity and then to return almost instantaneously to the point at which deflection began. This sudden return is called the FLY-BACK (q.v.) and its motion is usually invisible.

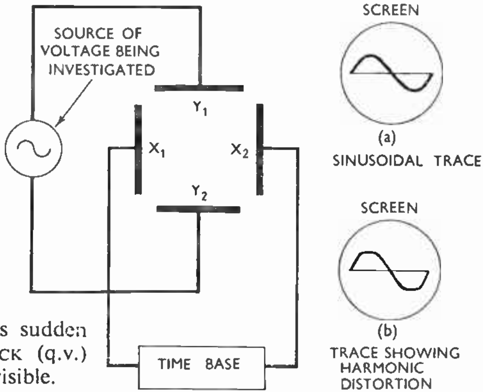


Fig. 24. Typical examples of the trace that may be produced on the screen of a cathode-ray tube when the voltage being examined is (*a*) sinusoidal, and (*b*) non-sinusoidal.

For a sinusoidal voltage on the Y plates and a saw-toothed voltage on the X plates, the trace of the screen takes the form of Fig. 24a. If the Y voltage is not sinusoidal (see HARMONIC DISTORTION), the nature of the distortion will be indicated on the trace (Fig. 24b).

For certain purposes, notably television reception, it is more usual to employ electromagnetic deflection instead of electrostatic deflection. In such cases, two pairs of deflector coils are placed outside the tube and so arranged that their respective electromagnetic fields produce horizontal and vertical deflection (see DEFLECTOR COILS). The principles of operation are similar to those appertaining to deflector plates.

A cathode-ray tube is termed an oscilloscope when used for measuring purposes; if permanent records of the trace are needed, a camera may be associated with the tube, in which case the instrument as a whole is known as an oscillograph, and the record thus obtained is called an oscillogram.

CATHODE SPUTTERING. Dislodgment from a cathode of particles of molecular size due to bombardment by positive ions of high energy. This eventually causes disintegration of the cathode, and is an anathema to valve makers and users.

CATHODE VOLTAGE. Synonym for CATHODE POTENTIAL.

CATION. Positively charged ion. A cation moves towards the negative electrode in an electrolytic cell (Fig. 25). See IONIZATION.

CAT'S WHISKER. Name given to the light spring contact used with certain types of CRYSTAL DETECTOR (q.v.).

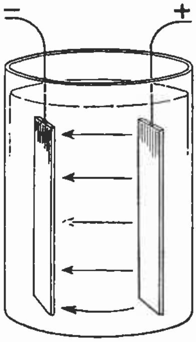


Fig. 25. In an electrolytic cell the cations, being positive, migrate to the negative electrode.

CAVITY RESONANCE. In an electro-acoustic device, for example, a loudspeaker or microphone, an artificial resonance produced by the formation of a cavity in the mechanical circuit to compensate for attenuation distortion in the circuit.

CAVITY RESONATOR. Space, usually simple in shape and enclosed by conducting surfaces, in which standing magnetic waves can be excited. See MAGNETRON, RHUMBATRON.

C-BATTERY. American term for GRID-BIAS BATTERY.

CELL. Device in which some action takes place to produce an electromotive force between electrodes forming the essential part of the cell. See ACCUMULATOR CELL, PHOTOCELL, PRIMARY CELL, SECONDARY CELL.

CENTIMETRE-GRAMME-SECOND SYSTEM OF UNITS. System which includes all units which are based on the centimetre as the measure of length, the gramme as the unit of weight, and the second as the time unit.

CENTIMETRIC WAVE. Radio wave of 1–10 cm. wavelength, that is, within a frequency range of 3,000–30,000 Mc/s. Centimetric waves are never refracted or reflected back to earth by the ionosphere and communication is established by means of the ground ray alone.

In general, reception is possible only within optical range of the sender, although signals have been received at distances considerably beyond the optical. Such reception appears to coincide with conditions of temperature inversion in the lower atmosphere.

The propagation characteristics of centimetric waves are similar to those of very high-frequency waves, the ground-ray attenuation increasing rapidly with frequency. See ABSORPTION, SUPER-FREQUENCY WAVE, VERY HIGH-FREQUENCY WAVE.

CERAMIC CAPACITOR. Form of capacitor having ceramic dielectric. See FIXED CAPACITOR, TRIMMER, VARIABLE CAPACITOR.

C.G.S. Abbreviation for centimetre-gramme-second. See CENTIMETRE-GRAMME-SECOND SYSTEM OF UNITS.

CHANNEL. Term based on a concept implying a frequency band wide enough to contain all or some of the frequencies of a group of waves representing a message transmitted by modulating a carrier wave, the frequency of which is not changed by the modulation.

When intelligence is communicated by electrical means, the communication is carried by a group of waves of different frequencies.

In order that several messages may be transmitted simultaneously through the same wave-transmitting medium, whether by radio, by physical conductors or by wave guides, each group of waves of comparable level must

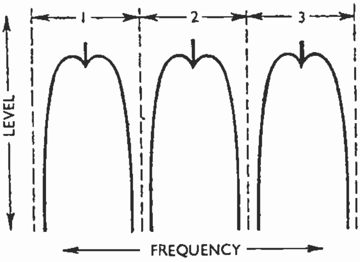


Fig. 26. Ideal arrangement of channels in a three-programme broadcasting system. Each curve represents the average level of sideband waves, and the centre line the carrier level.

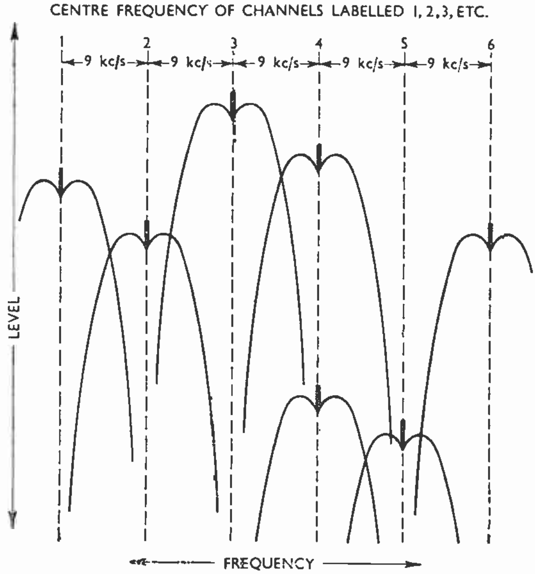


Fig. 27. Imaginary but typical illustration (in comparison with Fig. 26) of conditions in European broadcasting. In this case field strengths vary widely and, for example, channel 5 is occupied by a very low-power (or a very distant) sender which is blotted out by senders using channels 4 and 6.

occupy a different frequency band. In these circumstances, a selective receiver can pick up one group of waves and reject all other groups, and thus reproduce one message to the exclusion of all others (see SELECTIVITY). The different frequency bands occupied by the groups of waves representing different messages can be said to flow in different channels—in this case communication channels.

The terms "message" and "intelligence" can mean private telephone or telegraph messages on both sound and vision broadcast programmes, as well as the groups of waves used for the detection of otherwise invisible objects as in radar technique.

In the accompanying diagram of the diffusion of sound programmes in a broadcasting system (Fig. 26), field strength at any geographical location is plotted on a vertical axis, and wave-frequency on the horizontal axis. Fig. 26 illustrates an ideal state of affairs; but, in fact, the channels used by broadcasting stations in Europe are sometimes spaced too closely together and the sidebands overlap (Fig. 27). Because of this sideband overlap, the receiver must inevitably have a narrow band width and selects only those waves close to the carrier wave, cutting off those which represent the higher audio frequencies. The result is reproduction which lacks extreme "top." Only when a local station creates such an overwhelmingly strong field at the receiver that it dominates interference from the senders using frequency-contiguous channels, is it possible to get high-fidelity results. See CARRIER-WAVE TRANSMISSION, MODULATION, SIDEBAND, SIDEBAND WAVE.

CHANNEL DIVERSITY. See DIVERSITY SYSTEM.

CHARACTERISTIC DISTORTION. Distortion of the code units in a telegraphy transmission system. See MORSE CODE.

CHARACTERISTIC CURVE. Curve illustrating the manner in which the current of a valve electrode depends upon its potential or the potential of another electrode, all other potentials remaining constant.

CHARACTERISTIC IMPEDANCE. Iterative impedance of a quadripole when this has the same value at both pairs of terminals. Fig. 28 illustrates a quadripole, which may be either a

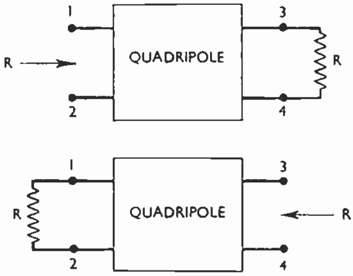


Fig. 28. When a quadripole has the same iterative impedance *R* measured at terminals 1 and 2 (terminals 3 and 4 being shunted by a resistance *R*) as measured at 3 and 4 (with 1 and 2 shunted), this equal iterative impedance is called the characteristic impedance of the quadripole.

network containing lumped reactance elements or a uniform transmission line, in which the iterative impedance measured at terminals 1 and 2 (with terminals 3 and 4 terminated in a resistance equal to the iterative impedance) is the same as that measured at terminals 3 and 4 (with terminals 1 and 2 terminated in a resistance equal to the iterative impedance). In this case, the iterative impedance is called the characteristic impedance of the quadripole to classify it as a particular form of iterative impedance (see ITERATIVE IMPEDANCE).

A quadripole which exhibits the same iterative impedance at both pairs of terminals must be symmetrical in itself; thus a filter section (Fig. 29) or a transmission line has a special iterative impedance, called its characteristic impedance. Fig. 30 illustrates the basic characteristics of a transmission line (see ARTIFICIAL LINE). Each series-inductive element and shunt-capacitive element, as well as the series-resistive element, is considered to be infinitely small; but there is an infinite number of elements.

As each shunt element subtracts a small current from the current flowing in the series arm, the series current will eventually be reduced to zero. There is thus no voltage across the conductors at the end of an infinitely long line. (In practice, infinite length can be considered to imply a line so long that the received voltage is substantively zero, although it must have some finite value, however small.)

Assuming a zero voltage at the end of the infinitely long line suggests that the sending-end impedance of the line will be the same whether the line end is short-circuited or open-circuited. In other words, the line is effectively terminated by a number of sections representing the line. Thus the infinitely long line is effectively terminated by its characteristic impedance, from which it may be concluded that the impedance of an infinitely long line is effectively isolated from its sending end by the infinite distance of separation. There can be no reflected wave from it; therefore, a line of finite length, terminated by a resistance equal to the characteristic impedance of the line, has no reflected wave to interfere with the sending-end impedance; apart from losses in the line itself, all the power fed into the sending end of a line, which is terminated in a resistance equal to the characteristic impedance of the line, is absorbed by this resistance.

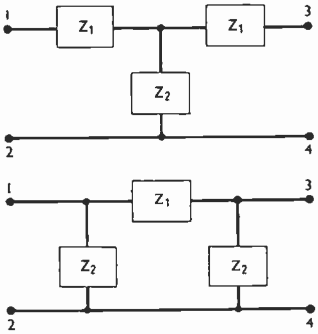


Fig. 29. Symmetrical filters having identical iterative impedance whether measured at terminals 1 and 2 or 3 and 4; this impedance is the characteristic impedance of the filter section.

It is, therefore, apparent that in feeding power to a load through a line, or through a cascade of symmetrical network sections, the best matching (i.e. maximum transfer of power to the load) occurs when the load has a resistance equal to the characteristic impedance of the line or network sections.

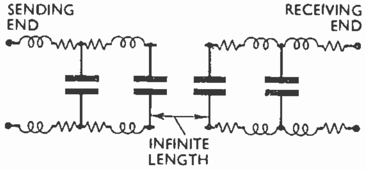


Fig. 30. Representation of a uniform transmission line of infinite length, consisting of series resistive and inductive elements and shunt capacitive elements. Voltage at the receiver is zero, impedance of the line being equal to its characteristic impedance.

The value of the characteristic impedance of a line or network depends upon the frequency of the waves passing through it. At frequencies for which the ratios of resistance per unit length to series reactance per unit length, and of leakance to shunt susceptance, are small, the characteristic impedance is $\sqrt{L/C}$, where L is the inductance and C the capacitance of the line per unit length. At very low frequencies (or D.C.), when the ratios specified are large, the characteristic impedance of the line approaches a value $\sqrt{R/G}$, where R is the resistance and G the leakance per unit length. In nearly all practical circumstances it is legitimate to take $\sqrt{L/C}$ as the characteristic impedance. See ITERATIVE IMPEDANCE, QUADRIPOLE, TRANSMISSION LINE.

CHARGE OF ELECTRICITY. Condition of electron excess or deficiency. If the number of "loose" electrons in a conductor is above the normal number, the conductor is said to be negatively charged; if the number is below normal, then the charge is called positive. The amount of an electric charge is measured in the unit of quantity, the coulomb. See COULOMB, ELECTROSTATICS.

CHARGING CURRENT. Current passed through an accumulator cell during the process of charging. The term may be used also to denote the direct current flowing into a capacitor; if there is danger of confusion, such a charging current should be described as a capacitor-charging current.

CHASSIS. Essential parts of a receiver or other apparatus, without cabinet or other container. It usually consists of a shallow metal tray, inverted as shown in Fig. 31, with large components such as variable capacitors mounted on the upper surface and small ones, such as resistors, underneath.

The metal tray, itself often described as a chassis, is customarily of mild steel with a non-rusting finish such as cadmium plating. Where large numbers are required to the same design, it is produced by stamping from sheet

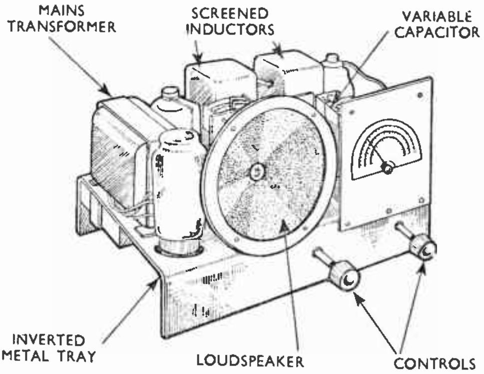


Fig. 31. Typical radio receiver chassis showing large components mounted on the upper surface of the metal tray, the smaller ones being accommodated underneath it.

metal. For smaller numbers, the metal blank is cut out with a guillotine and shaped on a bending machine.

CHECK RECEIVER. Receiver used to check the quality of a transmission, usually in close proximity to the sender.

CHEESE AERIAL. Reflector shaped as a sector of a paraboloid, as shown in Fig. 32, and containing a half-wave dipole; it is used at very high frequencies. The system produces a fan-shaped polar diagram, useful in radar and certain types of landing aids for aircraft, because it spreads out broadly in one plane but is narrowly defined in a direction at right-angles to the first.

CHOKE. Fixed inductor used generally in association with one or more capacitors to restrict alternating currents to a particular path. At audio frequencies the chokes used require high inductance, and have laminated-iron cores; but at radio frequencies a smaller inductance is adequate, and air or iron-dust cores are used.

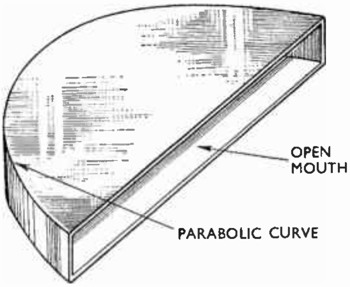


Fig. 32. Cheese aerial reflector as used for the production of narrow-beam radiation of centimetric waves from a half-wave dipole.

CHOKE COIL. Synonym for FIXED INDUCTOR.

CHOKE CONTROL. System of modulation. See ANODE MODULATOR.

CHOKE COUPLING. Synonym for INDUCTIVE COUPLING.

CHOKING COIL. Synonym for FIXED INDUCTOR.

CHOPPER. Device used for the production of A2 waves. The chopper

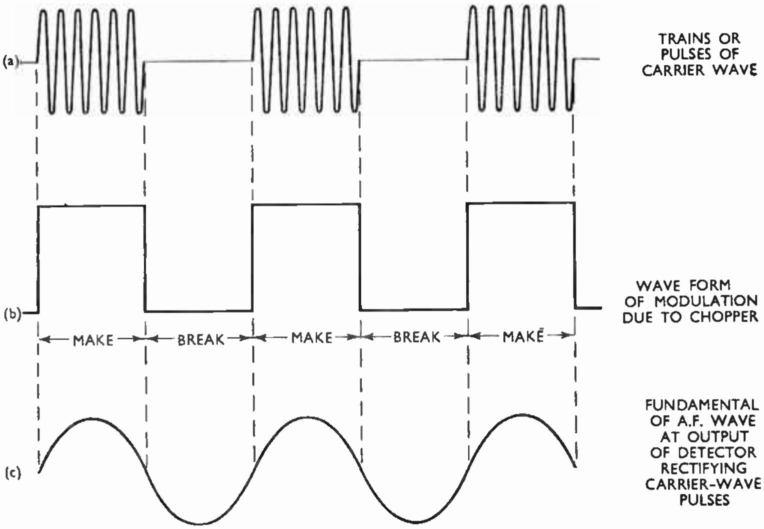


Fig. 33. Diagram showing a carrier wave (*a*) and the effect of a chopper (*b*). The audio-frequency wave (*c*), reproduced in the receiver, continues so long as the key is closed, thus messages may be transmitted by key and chopper in combination.

makes and breaks the circuit in which the carrier wave flows, so that the carrier wave is transmitted in periodic wave-trains. Fig. 33 illustrates the form of the carrier wave as transmitted; this is a form of pulse modulation because the time for which the carrier wave exists is the characteristic that is varied. See CARRIER-WAVE TRANSMISSION, MODULATION, PULSE MODULATION, TYPE A2 WAVE.

CIRCUIT. Path through which electricity flows continuously in a certain direction, or in which it flows alternately in one and then the other direction. A circuit may contain many branches but, if there is a single source of electricity, the current flowing from the source returns to the source and flows in a circuit connecting the terminals of the source. See ELECTROMOTIVE FORCE, NETWORK.

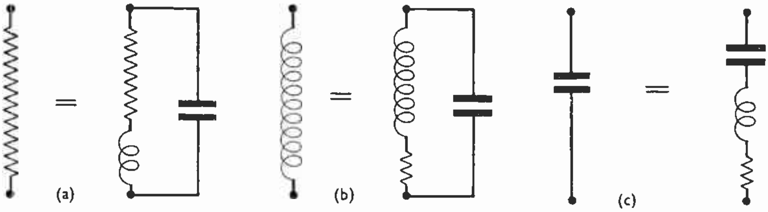


Fig. 34. Conventional representation of (*a*) resistor, (*b*) inductor and (*c*) capacitor as circuit components, together with their respective equivalent networks containing the reactive and resistive circuit elements which are inherent in them.

CIRCUIT-ELEMENT. Ideal resistor, inductor or capacitor considered as having respectively resistance, inductance and capacitance, and no other characteristic. In circuit theory it is desirable to assume that the circuit elements are "pure"—that a resistor has resistance but no reactance, and that a reactor has reactance but no resistance. It is not possible, however, to manufacture resistors that have no reactance, or reactors that have no resistance (see COMPONENT).

The reactance of a resistor becomes comparable with its resistance when the alternating currents flowing in it have very high frequencies. A resistor, whether it is wire-wound or of the carbon type, has both capacitance and inductance; and these can modify the impedance of the resistor when the wave frequency is high. All capacitors have resistance and inductance, although these are of relatively very small magnitude. The resistance of an inductor is often an extremely important characteristic of it (see Q-FACTOR).

Components which are used in practice as resistors and reactors may be considered as made up of circuit elements (Fig. 34). Naturally, in many cases—notably when the wave frequency is low—it is permissible to overlook the reactive properties of resistors and the resistive property of capacitors; it is, however, seldom permissible to overlook the resistive properties of inductors, except in dealing with simplified conceptions, for the Q-factors of inductors are usually lower than those of capacitors. See POWER FACTOR, Q-FACTOR, REACTANCE, RESISTANCE.

CIRCULARLY POLARIZED WAVE. Radio-wave whose plane of polarization is rotating from a vertical to a horizontal plane. Such waves are important only when the reception of short-wave stations at long distances is attempted. See CIRCULAR POLARIZATION, POLARIZATION.

CIRCULAR POLARIZATION. Polarization, the plane of which is rotating, of radio-waves after reflection in the ionosphere. It is found that, after reflection by an ionospheric layer, the plane of polarization is modified; nor is it a simple twist such as a vertically polarized wave emerging from the layer horizontally polarized. The plane of polarization is usually rotating; the first few waves may be vertically polarized, the next batch may be slightly off the vertical, and so on, until, after a brief interval, the waves are found to be horizontally polarized. The process goes on repeating itself, the time taken to complete a change of polarization depending upon the ionospheric conditions. Such waves are said to be circularly polarized.

More often than not, the amplitude of the wave varies with the direction of polarization; for example, the field strength of the wave may be greater when the polarization is vertical than when it is horizontal, so that there is a cyclic variation in amplitude as well as polarization. Waves of this nature are said to be elliptically polarized.

Rotation of the plane of polarization is produced by the effect of the earth's magnetic field on the ionized layers. The motion of electrons in the E- and F-layers, which is caused by the passage of the ionospheric wave, is affected to some extent by the earth's magnetic field.

The wave is split into two components, having different paths through the layer and attenuated to different degrees. They are found to be circularly polarized and rotate in opposite directions. When the two components combine, having been reflected by the layer, the wave is usually found to be elliptically or circularly polarized. This accounts for the fact that, when receiving long-distance, high-frequency transmission, equally good results are obtained with either horizontal or vertical receiving aerials. The nature of the sending aerial is unimportant. See PLANE OF POLARIZATION, POLARIZATION.

CIRCULAR SCANNING. Deflection of the beam in a cathode-ray tube so that the spot traces out a circular or elliptical path on the screen.

CIRCULAR TIME BASE. Circuit developing suitable potentials for application to the plates or deflector coils of a cathode-ray tube to produce circular scanning. In its most simple form, a circular time base may consist of a resistor and capacitor connected in series and fed from an A.C. source, one pair of plates (or deflector coils) being connected across the resistor and the other pair (or coil) across the capacitor. A circular trace is obtained when the reactance of the capacitor at the frequency of the supply equals the value of the resistor; otherwise the trace is elliptical.

CLASS-A, CLASS-AB, CLASS-B, CLASS-C AMPLIFIERS. See CLASS-A (ETC.) VALVE OPERATION.

CLASS-AB VALVE OPERATION. Method of working a valve in which the grid bias is somewhat greater than is required for operation at the mid-point of the straight-line portion of the characteristic curve which lies to the left of the grid-zero line.

When the valve is working in the intended manner, the anode current of a class-AB amplifier is driven down to cut-off by each negative swing of the signal voltage. The standing, or no-signal, anode current is somewhat less than in class-A but not so low as that of class-B operation. See CLASS-A VALVE OPERATION.

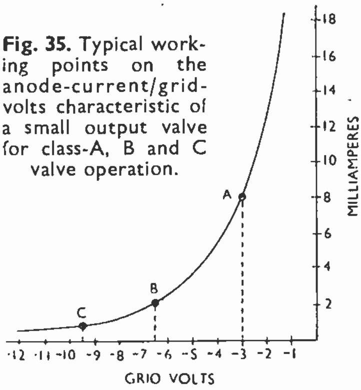


Fig. 35. Typical working points on the anode-current/grid-volts characteristic of a small output valve for class-A, B and C valve operation.

CLASS-A MODULATION. Amplitude modulation in which the modulating-wave amplifier is a class-A type. See CLASS-A VALVE OPERATION.

CLASS-A VALVE OPERATION. Method of working a valve so that no grid current flows, and so that the operating point sweeps over the straight part of the characteristic curve (Fig. 35). In effect, this means adjusting the grid bias to a point near the middle of that straight part of the curve which lies to the left of the zero grid-volts line, and ensuring that the input voltages are not so great as to cause grid current or rectification at the lower bend of the curve. See CLASS-AB, CLASS-B, CLASS-C VALVE OPERATION.

CLASS-B MODULATION. Amplitude modulation in which the modulating-wave amplifier is a class-B type. See CLASS-B VALVE OPERATION.

CLASS-B VALVE OPERATION. Method of working a valve wherein the grid bias is sufficient to bring the standing anode current down to the cut-off point, that is, to or below the elbow at the bottom of the anode-current/grid-volts curve. Appreciable amounts of anode current therefore flow only when the valve is actually handling signals. See CLASS-A VALVE OPERATION.

CLASS-C VALVE OPERATION. Method of working a valve wherein the grid bias is sufficient to reduce the anode current well below the cut-off point. With a given signal input, the power output is then proportional to the anode voltage; this method of working a valve is chiefly of interest in sender circuits. See CLASS-A VALVE OPERATION.

C-LAYER. Ionospheric layer believed to exist at a height of between 15 and 20 miles above the earth. Pulse measurements indicate that a layer may be present at this height, but its characteristics appear to be very variable and, at present, no definite information in this connexion is available. See IONOSPHERE.

CLICK METHOD. Method used for finding the resonant frequency of an oscillatory circuit by means of a heterodyne wavemeter and a pair of headphones. The heterodyne wavemeter incorporates a calibrated oscillator which, when adjusted to the frequency of the circuit being tested, produces a single click in the headphones. The resonant frequency of the oscillatory circuit is then read from the dial of the wavemeter.

CLOSE COUPLING. Conditions existing when the coefficient of coupling between inductors is large. If a band-pass filter is formed by two inductively coupled tuned circuits, the circuits are said to be close-coupled when the mutual inductance between the two inductors has a relatively large value; that is, the coupling coefficient of the inductors exceeds, say, 0·5. The closer the coupling, the farther apart the peaks in the filter response curves (see BAND-PASS FILTER).

A more general definition of close coupling is applied to arrangements in which energy is passed from one circuit to another by inductive coupling. Thus, the greater the mutual inductance between the inductive elements by means of which the coupling is made, the closer the coupling is said to be, and the more complete the exchange of energy between the circuits. See BAND-PASS FILTER, COUPLING, COUPLING COEFFICIENT, INDUCTIVE COUPLING, MUTUAL INDUCTANCE.

CLOSED CIRCUIT. Oscillatory circuit in which an inductor is connected in parallel with a capacitor. In the early days of broadcasting, the term was used to describe a sender having its output terminals connected to a parallel-tuned circuit. This is chosen to simulate the electrical characteristics of the aerial normally used; the sender does not radiate energy connected to a closed circuit (see DUMMY AERIAL).

Programme executives employ the phrase "working on closed circuit," by which they mean that the programme is not radiated and not heard by listeners. See OSCILLATOR, RESONANCE.

CLOSED-CIRCUIT SYSTEM. In telegraphy, a system in which a continuous flow of current is maintained, signalling being available to any station by the control of this current.

CLOSED-CIRCUIT WORKING. Fire-alarm system in which a current is normally maintained in a line which passes through each of the call points. When the handle is operated at a call point, the current is interrupted and an alarm is sounded at the fire station See OPEN-CIRCUIT WORKING.

C-NETWORK. Network composed of three impedances. The free ends of the series arms are connected to one pair of terminals, and the junctions of the two series arms and the single shunt impedance are connected to another pair of terminals. The C-network (Fig. 36) is the balanced form of the L-network. See NETWORK, QUADRIPOLE.

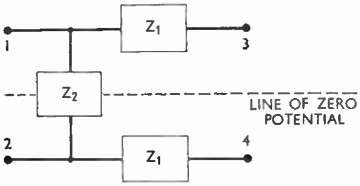


Fig. 36. Arrangement of the impedances forming a C-network; it is the balanced form of L-network.

COASTAL REFRACTION. Deviation of a radio-wave at the point where its path, having passed over water, becomes a path over land or vice versa. Radio-waves, being of an electromagnetic nature, are bent or refracted from their normal path when passing from one medium to another. A change in the conductivity of the surface over which a wave passes, or a change in the relative permittivity of the surface, is sufficient to constitute a change of medium and bring about some refraction of the wave.

The velocity of a radio-wave over sea water may be up to 5 per cent greater than that over land, as salt water, because of its higher conductivity, has less dragging effect on the "feet" of the wave. If a wave crosses the coast at an angle of less than 20 deg., refraction is appreciable and the bearing of the wave is no longer that of the sender. The effect varies with the frequency of the wave, but below about 150 kc/s the refraction appears to be independent of frequency.

As refraction of a radio-wave is almost always accompanied by a change of polarization, some form of fading may be experienced at the receiver.

The effect is of most importance when taking bearings by direction-finding methods, and ships at sea have to allow for errors introduced by coastal refraction. A bearing may be as much as 10 deg. in error and careful perusal of charts is necessary to determine whether refraction is likely to be important. Fig. 37 illustrates how coastal refraction occurs. See DIFFRACTION, DIRECTION-FINDING, POLARIZATION, REFRACTION.

CO-AXIAL CABLE. Cable containing one or more co-axial pairs. See CO-AXIAL PAIR.

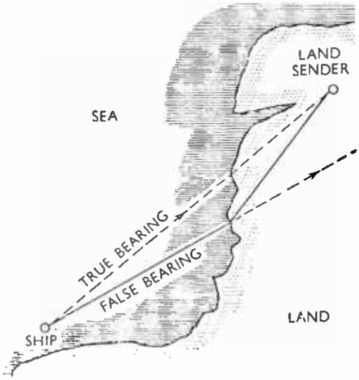


Fig. 37. Example of the false bearing obtained due to coastal refraction; the error may be as high as 10 deg.

CO-AXIAL PAIR. Pair of conductors, one surrounding but insulated from the other. Both conductors have the same axis, hence the term co-axial describes the form of the transmission line. A useful feature of the co-axial pair (Fig. 38) is that, at high wave frequencies, it gives less attenuation than an ordinary two-pair cable of the same length. Co-axial pairs are used for transmitting modulated carrier waves carrying intelligence: a great many messages can be transmitted by one co-axial pair, and television programmes involving a very wide frequency band may be carried over long distances. Repeaters are inserted in the cable at distances varying between five and ten miles. See CARRIER, CARRIER-WAVE TRANSMISSION, TRANSMISSION LINE.

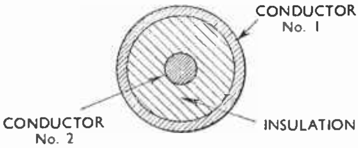


Fig. 38. Section through a co-axial pair, showing that the axes of the two circular conductors coincide.

CO-AXIAL TUBE FEEDER. Co-axial pair consisting of concentric tubes, used in connecting the aerials to the senders in short-wave radio stations (Fig. 39). See CO-AXIAL PAIR, FEEDER.

COEFFICIENT OF COUPLING. See COUPLING COEFFICIENT.

COEFFICIENT OF DETECTION. See DETECTION COEFFICIENT.

COEFFICIENT OF MUTUAL INDUCTION. Synonym for MUTUAL INDUCTANCE.

COEFFICIENT OF SELF-INDUCTION. See INDUCTANCE.

COGGING. Condition in which oscillations from an outside source cause an oscillator to synchronize with these oscillations, rather than oscillate at its natural frequency. If an oscillator is coupled to a source of oscillation, and the oscillations from the outside source are of invariable frequency, the effect of cogging is to drag the oscillator into synchronism with the oscillations flowing in the external circuit. If two oscillators are coupled together, cogging will cause both oscillators to oscillate at the same frequency although they would both oscillate at a different frequency if there were no coupling between them.

Cogging can occur only when an oscillator is producing a frequency not very different from that of the oscillations with which it cogs. The closer the coupling, the greater the change of frequency of the oscillator from its free to its cogged condition. Cogging may cause a local oscillator in a frequency-changer system to be dragged into synchronism with the other wave essential to the system; for example, the local oscillator in a superheterodyne may cog with the signal-wave frequency. See BEAT-FREQUENCY OSCILLATOR, BEAT OSCILLATOR, BEAT RECEPTION.

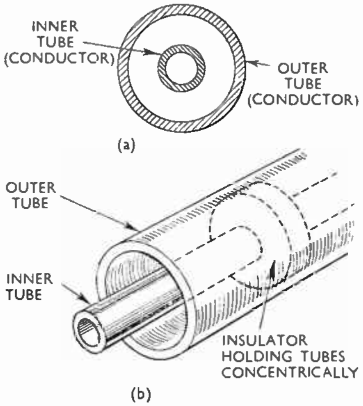


Fig. 39. Co-axial tube feeder shown (*a*) in section and (*b*) in perspective. A feeder of this type is frequently employed to conduct currents from a short-wave sender to its aerial.

COHERER. Early form of detector used in the first practical reception of wireless waves. It consists of a glass tube containing metal filings. This normally has a high resistance, but the passage of a radio-frequency current through the filings causes them to cohere and become conducting. It is necessary to re-set the device, after the passage of the R.F. current, by shaking up the filings again. This is achieved by tapping the glass tube, usually by means of an electromagnet operating a tapper.

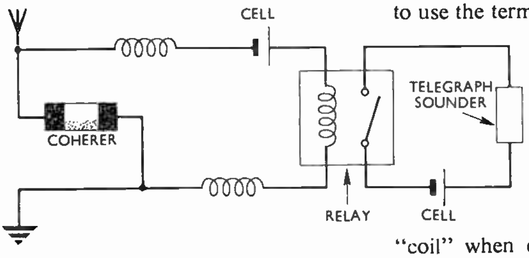


Fig. 40. Circuit diagram of the first Marconi receiver; the form of detector employed was a coherer.

The signal itself can be made to operate the tapper and, in this case, the device becomes self-restoring. The circuit of the first Marconi receiver, used in 1896, is shown in Fig. 40.

COIL. Number of turns of insulated and conductive wire, wound close to one another. The coil so formed may be of circular, rectangular or square form (Fig. 41). It is characterized in electrical work by having the property of inductance. An inductor is often described as "a coil"; but it is better to use the term "inductor" rather than "coil" when describing a component having predominantly the property of inductance. See CORE, INDUCTANCE, INDUCTOR.

COIL AERIAL. Synonym for LOOP-AERIAL.

COIL DRIVE. Synonym for inductive drive.

COIL LOADING. Synonym for inductance loading.

COLD CATHODE. Cathode electrode of a glow-tube. The term is used when the current in the tube is due to ionization of a gas and, therefore, when no primary electrons are available at the

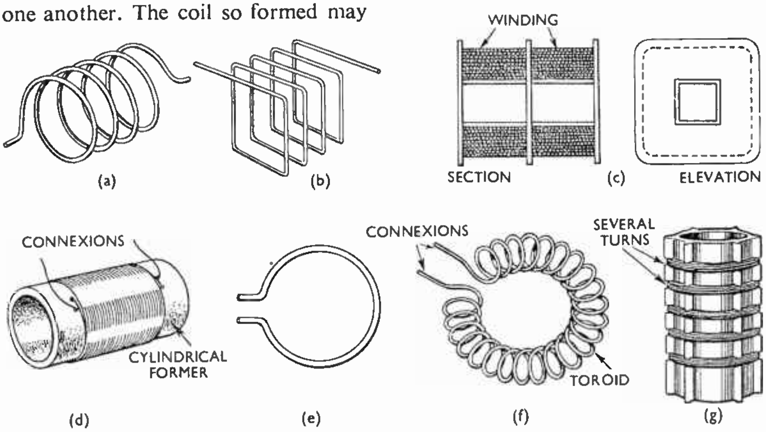


Fig. 41. Coils may take a number of different forms. Those illustrated are: (*a*) helical coil; (*b*) square coil; (*c*) two-section coil wound on a square-core former; (*d*) single-layer solenoid; (*e*) single-turn coil; (*f*) toroidal coil, and (*g*) sectionalized type of multi-layer coil which is wound on a ribbed and suitably slotted former.

cathode to start the process of conduction. See COLD-CATHODE VALVE, GLOW-TUBE.

COLD-CATHODE DETECTOR. Detector of the thermionic type in which the cathode is not heated. Certain types of valve have been developed for telephone circuits, such such as gas-filled triode, but with an unheated cathode. Such valves, however, are not employed in radio practice to any extent.

COLD-CATHODE VALVE. Valve containing a cathode which emits electrons without the application of heat. Such a valve needs no heater supply. Some rectifiers, voltage regulators and thyratrons are of this type.

The cold-cathode diode contains an inert gas under slight pressure; discharge begins when the anode-cathode potential reaches a certain value, usually between 60 and 180 volts, but the potential can be reduced slightly once the discharge starts. The stability of the discharge is improved by treating the cathode with metals or oxides of low work function.

If a third electrode is placed near the cathode in such a diode, any discharge occurring between these electrodes starts the main discharge between anode and cathode.

To use this type of cold-cathode triode thyratron, the anode/cathode potential is adjusted to just below the ionization potential, and a high resistance is connected in series with the grid or starter electrode to keep this electrode current low. A few volts applied to the starter electrode then initiates the main discharge. See COLD CATHODE, GAS-FILLED TRIODE.

COLOUR CODE. System of coloured markings frequently used on capacitors and resistors to indicate value.

Dots or bands of colour are placed nearer to one end of a capacitor and are read in order from that end, unless an arrow indicates otherwise. The respective values indicated by the different colours are shown in the table below.

The colours may be arranged in groups of one, two, three or five. One colour only indicates *tolerance*, the remaining designations being given numerically. Two colours only indicate *tolerance voltage* and *rating* respectively. When there are three colours, the first two indicate the first two significant *capacitance* figures and the third the decimal multiplier, the tolerance and rating being given in figures.

With five colours, the first three indicate *capacitance*, as with three colours, and the fourth and fifth indicate *tolerance* and *voltage rating* respectively. When five colours are

CAPACITOR COLOUR CODE

Colour	*Significant Figure*	*Decimal Multiplier*	*Tolerance Percentage*	*Voltage Rating*
Black	0	1	—	—
Brown	1	10	1	100
Red	2	100	2	200
Orange	3	1,000	3	300
Yellow	4	10,000	4	400
Green	5	100,000	5	500
Blue	6	10^6	6	600
Violet	7	10^7	7	700
Grey	8	10^8	8	800
White	9	10^9	10	1,000
No colour	—	—	20	500

used they may sometimes be arranged in two groups, in which case the three-figure group indicates capacitance and the two-figure group tolerance and voltage rating respectively. In all cases the capacitance is given in micromicrofarads.

RESISTORS. Two main systems are employed for the colour-coding of resistors (Fig. 42):

Three-band System. With this system the resistance value is indicated by three coloured bands; the bands are placed near one end of the resistor and, reading from this end, the first two bands indicate the first two significant figures and the third band the decimal multiplier, the colours having the values indicated in the table below. For example, a resistor having bands of red, green and orange in the order indicated above would have a nominal resistance of 25,000 ohms.

Single Spot or Band System. With this system, the first significant figure is indicated by the colour of the body, the second significant figure by the colour of the tip, and the decimal multiplier by the colour of the single band or spot on the body. In applying this system confusion may arise when the first significant figure is identical with the decimal multiplier, for, in this case, the colours of the spot and body are the same, and therefore no spot is seen.

Examples: Brown body, grey tip, yellow spot; value 180,000 ohms.

Red body, green tip; value 2,500 ohms.

It should be noted from the table that tolerance percentage is sometimes indicated by additional markings as follows: gold ± 5 per cent, silver ± 10 per cent. If no such marking appears on the resistor a tolerance of ± 20 per cent can be assumed.

COLPITT'S CIRCUIT. Thermionic-valve oscillator circuit consisting essentially of capacitive links between anode and cathode, and grid and cathode, and an inductive link between anode and grid, as shown in Fig. 43. The frequency of oscillation is given by $f = \frac{1}{2\pi\sqrt{LC}}$, where $C = \frac{C_1 C_2}{C_1 + C_2}$.

COMA. Distortion of the stationary spot on the screen of a cathode-ray tube, the image being pear-shaped instead of circular.

COMBINATION-TONE DISTORTION. See INTERMODULATION DISTORTION.

COMBINATION TONES. Tones produced by amplitude distortion in

RESISTOR COLOUR CODE

Colour	*Significant Figure*	*Decimal Multiplier*	*Tolerance Percentage*
Black	0	1	—
Brown	1	10	—
Red	2	100	—
Orange	3	1,000	—
Yellow	4	10,000	—
Green	5	100,000	—
Blue	6	10^6	—
Violet	7	10^7	—
Grey	8	10^8	—
White	9	10^9	—
Gold	—	0·1	± 5
Silver	—	0·01	±10
No colour	—	—	±20

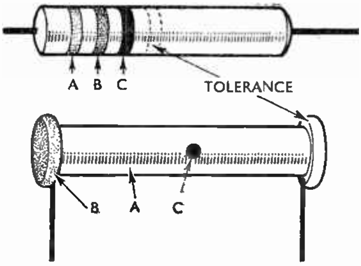


Fig. 42. Two forms of colour coding as applied to fixed resistors. The colours are "read" in the alphabetical order indicated, *A* and *B* representing the first two significant figures, and *C* the decimal multiplier. A fourth colour, which is sometimes added, refers to the percentage tolerance.

the human ear. They arise when the ear is subjected to more than one frequency at the same time, and have frequencies which are the sums and differences of the applied frequencies. See INTERMODULATION DISTORTION, SPEECH AND HEARING.

COMMON AERIAL. Aerial used in radar and other special applications for both sending and receiving. Some form of automatic switching, such as a gaseous spark-gap, is necessary to protect the receiver from the sending power. The gap breaks down at each sending pulse and short-circuits the receiving feeder line. If the short-circuit is located one quarter wavelength from the point at which the receiving line branches from the common feeder, it shunts a very high impedance across the sending line, and absorbs none of the sending power. See QUARTER-WAVELENGTH LINE.

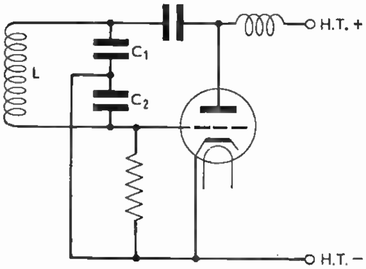


Fig. 43. Diagram which shows the fundamentals of Colpitt's circuit.

COMMON-FREQUENCY BROADCASTING. Synonym for SHARED-CHANNEL BROADCASTING.

COMMON-IMPEDANCE COUPLING. Coupling of two circuits by the inclusion of an impedor in both circuits. The term is sometimes abbreviated to "impedance coupling." See CAPACITIVE COUPLING, INDUCTIVE COUPLING, RESISTIVE COUPLING.

COMMON RETURN. A single conductor which in some way provides a return path for currents which have made part of their journey by separate paths, and which merge in the common return.

COMMON-WAVELENGTH BROADCASTING. Synonym for SHARED-CHANNEL BROADCASTING.

COMMUTATION MODULATION. Modulation in which switches, usually electronic, are used to cause periodic alterations of the circuit path of the carrier wave. There are many forms of commutator modulators, the most commonly used being the ring modulator (see RING MODULATOR). The basic principle lies in the changing of the path in which the modulating wave is flowing to produce a rectangular wave. Fig. 44 shows a form of this wave and the circuit which produces it. The frequency of reversal of circuit path is the frequency of the equivalent carrier wave.

It can be demonstrated that a commutation-modulated wave can be resolved into a number of waves. If f_c be the frequency of the reversals and f_m the frequency of the modulating wave, then the wave of Fig. 44b is composed of waves of frequency $f_c + f_m$, $f_c - f_m$, $3f_c + f_m$, $3f_c - f_m$, $5f_c + f_m$, $5f_c - f_m$ up to $nf_c + f_m$ and $nf_c - f_m$, where n is odd and theoretically infinity. The relative amplitude of the waves is 1, $\frac{1}{3}$, $\frac{1}{5}$, and so on up to $\frac{1}{n}$, so that if n

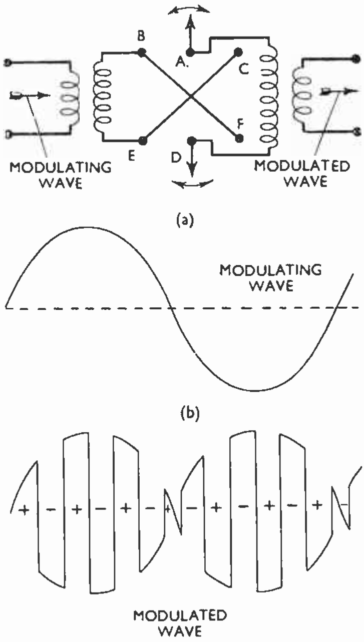


Fig. 44. Commutation modulation is effected if the switch (*a*) is changed over periodically so that the modulating wave (*b*) is altered to the modulated form shown below it; this contains a component wave representing a suppressed-carrier modulation.

is infinity, waves of frequency nf_c+f_m and nf_c-f_m have zero amplitude and infinite frequency. In practice, a filter can be used to transmit waves of frequency f_c+f_m and f_c-f_m to give a suppressed-carrier amplitude-modulated wave. If the filter passes waves of frequency f_c+f_m or f_c-f_m, single-sideband modulation is produced.

The frequency of reversal is the frequency of the reversals of the switch (Fig. 44). Electronic switches are generally used because the carrier frequency is, in most cases, too high to enable a mechanical switch to respond. If the carrier-wave frequency were of the order of 1,000–2,000 c/s, however, a rotating commutator could provide the reversals. Reversal of the circuit path may also be simulated by opening and short-circuiting the circuit path periodically. In this case, the carrier wave is not suppressed. See SUPPRESSED-CARRIER MODULATION.

COMMUTATOR. Cylindrical structure of copper bars insulated from one another and constituting the means of rectifying the current of a dynamo, or of reversing the current in the windings of a D.C. motor (see MOTOR). Commutators are also used on some types of A.C. motor.

COMMUTATOR MODULATOR. Modulator in which switches (usually electronic) are used to cause periodic alterations of amplitude (or reversal of direction) of the carrier wave. The commonest form of commutator modulator is the ring modulator. See COMMUTATION MODULATION, RING MODULATOR.

COMPANDER. In telephone speech transmission, a device combining the functions of an expander and a compressor. Its effect is to increase the volume of soft speech and reduce the loud components, thus reducing contrast and increasing the signal-to-noise ratio. See EXPANDER, COMPRESSOR.

COMPENSATED-LOOP DIRECTION FINDER. Device for avoiding errors in loop direction-finders owing to night effect by the use of a horizontal aerial which rotates with the loop. Night effect is caused by voltages induced in the horizontal members of the loop by horizontally-polarized downcoming waves which have been reflected at the ionosphere. These voltages can be partially neutralized and night effect eliminated to a certain extent by suitably combining with the loop output the output of the horizontal aerial mentioned. See DIRECTION-FINDING, NIGHT ERROR.

COMPLETE CYCLE. Synonym for CYCLE.

COMPONENT. Manufactured article which is used to form a part of an apparatus when connected to other components to form circuits. Generally speaking, a component does not of itself perform any function; a resistor is a component, but by itself and without being connected in circuits to other components, it is of no functional significance.

Examples of what are called components include valves, inductors, capacitors, resistors, valve holders, terminals, switches, transformers and so on. On the other hand, a relay, calibrated attenuator, beat-frequency oscillator or signal generator are all examples of "apparatus," while a "broadcasting sender" is an "equipment." See APPARATUS, INSTRUMENT, MEASURING INSTRUMENTS.

COMPONENT OF ERROR. One of the many errors possible in readings obtained from a direction-finder. The term is generally used in referring to a specific type of error; for instance, quadrantal component of error.

COMPRESSOR. Electronic amplifier used in telecommunication and radio circuits for reducing contrast between extremes of speech or music volume. It permits the transmission of higher mean volume, thus increasing the signal-to-noise ratio. See COMPANDER, EXPANDER, LIMITER.

CONCENTRIC CABLE. Synonym for CO-AXIAL CABLE.

CONCENTRIC LINE. Synonym for CO-AXIAL PAIR.

CONCENTRIC TUBE FEEDER. Radio-frequency conductor which consists of a single wire centrally spaced in a metal tube or sheath. Feeders of this kind are sometimes used, on the higher frequencies particularly, to connect a receiving station to its distant aerial-system, and they are occasionally employed even to carry the output of a sender to the aerial.

Such a feeder system is, of course, well screened and will not radiate; moreover its impedance is fixed by the construction of the tubular conductors and does not require to be maintained by careful spacing and mounting of the two lines, which can be as near together or far apart as may be convenient. This is of some slight advantage at certain points in an aerial installation.

In a common form, a feeder of this type consists of a copper tube, perhaps half an inch in bore, with a single conductor of about 18 S.W.G. held in a central position by pointed ceramic-bead spacers (Fig. 45). For sending purposes, the tube would naturally be larger, perhaps 2 or 3 in. in diameter. In either case, the interior of the feeder system must be kept free from moisture, and it is sometimes filled with nitrogen or dried air under pressure.

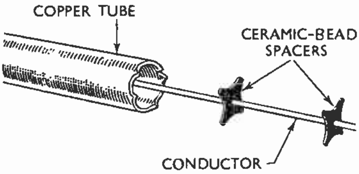


Fig. 45. Concentric-tube feeder in which ceramic beads are used to ensure central spacing of conductor.

CONDENSER. Obsolescent term for CAPACITOR.

CONDUCTANCE. Property of any material which allows it to pass an electric current. The possession of this property to a marked degree is the characteristic of those materials which are known as conductors; numerically, the conductance of a circuit is equal to the reciprocal of its resistance.

CONDUCTION. Process whereby an electric current is led along a definite path. The term conduction current is sometimes used to differentiate between a current in a conductor and one consisting of a stream of electrons projected across an evacuated space, as in a thermionic valve.

CONDUCTIVITY. Property, of a substance such as a metal, of being able to conduct an electric current with a particular degree of ease. More precisely, conductivity is a measure of the conductance of a given material under specified conditions, such as between the faces of a cube of standard size at a certain temperature. See CONDUCTANCE.

CONDUCTOR. Material capable of conducting an electric current with ease, as distinct from a non-conductor or insulator which does so with such difficulty that for all practical purposes it may be regarded as having zero conductivity or infinite resistance. Alternatively, a wire, cable or other path for currents (Fig. 46). See CABLE, WIRE GAUGE.

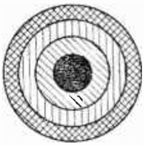


Fig. 46. In a power cable the conductor is the metal core (shown solid black in this section diagram). The core may be surrounded by a layer or layers of insulating material, a layer of armouring and, finally, a waterproof layer (shown cross-hatched).

CONE AERIAL. Synonym for CONICAL AERIAL.

CONE DIAPHRAGM. Diaphragm of a loudspeaker, taking the form of a cone, driven at its apex by a vibrating reed (moving-iron) or by an attached coil, moving at the frequency of the applied signals (moving-coil). See LOUDSPEAKER.

CONE LOUDSPEAKER. Any loudspeaker using a cone diaphragm.

CONICAL AERIAL. Wide-band aerial; that is, one which is designed to cover a considerable band of frequencies. The cone is a half-wave dipole consisting of two wire cages, each tapering to a point at the dipole centre; thus there are in fact two skeleton cones with points towards each other, as in the diagram (Fig. 47). In some cases, and for centimetric wavelengths, sheet-metal cones are used.

CONICAL-HORN AERIAL. Aerial used at centimetric wavelengths, much resembling a loudspeaker horn with exponential flare; when suitably proportioned such an aerial is strongly directive. It is normally fed with energy from a wave-guide leading into its throat. See WAVE-GUIDE.

CONJUGATE IMPEDANCES. Impedances each having equal resistance, and reactance of equal magnitude but of opposite sign. Reactances which have the same magnitude but opposite sign are capacitive and inductive reactances of equal reactance value. For example, the reactance of an inductor of inductance L is ωL, and the reactance of a capacitor is $\frac{1}{\omega C}$, ω being $2\pi f$ where f is the frequency of the wave passing through the reactors. At some value of ω, $\omega L = \frac{1}{\omega C}$ and the numerical values of the reactances of inductor and capacitor are equal. But, if the same current flows through both reactors, the voltages across them, assuming there is no resistance, are 180 deg. out of phase, and so cancel; thus the reactances are said to have "opposite signs." See IMPEDANCE, REACTANCE, VECTOR.

CONSTANT-AMPLITUDE RECORDING. In electrical recording, a term used when the amplitude of the recorded wave form is constant at all frequencies for a constant-voltage, variable-frequency input to the equipment. See CONSTANT-VELOCITY RECORDING.

CONSTANT-CURRENT MODULATOR. Synonym for ANODE MODULATOR.

CONSTANT-FREQUENCY OSCILLATOR. See FREQUENCY-STABILIZED OSCILLATOR.

CONSTANT-VELOCITY RECORDING. In electrical recording, term used when the velocity of the recorded wave form remains constant for a constant-voltage, variable-frequency input to the equipment. Velocity and amplitude are related: Velocity (r.m.s.) $= 4{\cdot}44\,fa$ cm/sec., where f is the recorded frequency and a the amplitude of the waves. Therefore, with constant velocity, the amplitude is inversely proportional to frequency.

CONTACT POTENTIAL. Difference in the characteristic affinity for electrons of the various parts of the structure of a thermionic valve, such as the anode and cathode. The contact potentials of grid and cathode affect the position of the cut-off point on the characteristic of the valve.

CONTACT VOLTMETER. Voltmeter in which the movement of the instrument actuates contacts for alarm and other purposes.

CONTINUITY CONTROL. Function of keeping a watch on the programme presentation as a whole and smoothing over gaps between programme items; or the stage management of a programe when schedules are upset.

Each programme item is generally introduced by an announcer. On changing from one item to another, new studios come into use, and the new item will most probably be introduced by a new announcer and a short delay may take place. Continuity control ensures that there shall be a smooth change-over. Thus, while flashing of warning lights, hushing of performers and so forth goes on in the studio about to go on the air, the continuity-control announcer makes the fade-outs and fade-ins, while placing his own microphone in circuit to announce the programme.

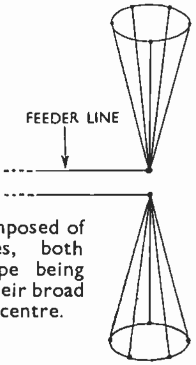


Fig. 47. Form of wide-band half-wave dipole, using a pair of tapering cage structures, known as a conical aerial. A diamond aerial is composed of similar . structures, both cages in this type being inverted so that their broad ends are at the centre.

The circuits are further arranged so that the continuity controller can fade out any studio and put himself in control through his own microphone. This, when it has been used, is faded out as the new item starts. See FADER, STUDIO-CONTROL CUBICLE.

CONTINUOUS CURRENT. Synonym for DIRECT CURRENT.

CONTINUOUS WAVE. Synonym for TYPE A0 WAVE.

CONTRAST AMPLIFICATION. Form of amplification by which the contrast between soft and loud passages in a radio-broadcast programme is accentuated. The gain of the amplifier is automatically reduced on soft, and increased on loud passages. It is designed to counteract the compression of the volume range introduced into the transmitting system for the purpose of maintaining adequate signal-to-noise ratio. See COMPANDER, COMPRESSOR, EXPANDER, LIMITER.

CONTRAST CONTROL. Control of the variation of brightness of a television picture for a given change in signal amplitude.

Change in the brightness of any part of a picture is judged, not by the actual magnitude of the change, but by the magnitude in relation to the original brightness. Therefore, the initial brightness of the cathode-ray tube must be taken into account when contrast control is required.

If contrast in a picture is to be increased, the method adopted is to increase the gain of the amplifier, but this in itself will not completely provide the required contrast because the brightness control must be adjusted also. In general, the brightness must be reduced when the contrast is increased, and the brightness increased when the contrast is reduced.

CONTROL ELECTRODE. Any electrode the potential of which controls the current flowing between two other electrodes. In a valve the usual controlling electrode is known as the CONTROL GRID (q.v.); in a cathode-ray tube it is known as the MODULATOR ELECTRODE (q.v.).

CONTROL GRID. Electrode of the grid type nearest to the cathode (Fig. 48). The control grid is the electrode which, for a given change of its potential, produces the largest change of anode current. In most amplifier circuits the wave to be amplified varies the potential of the control grid with respect to the cathode.

The anode current in an ordinary amplifying hard-vacuum valve is determined by the potential gradient at the cathode. Since the control grid is nearly always very close to the cathode, its potential has a predominating influence in determining the potential gradient at the cathode.

The term "grid" is constantly used instead of control grid; this is partly a survival from the days before the tetrode, pentode, hexode and other complex valve types came into use, when only the triode with its single grid was available. Moreover, as the other grids are distinguished by the terms screen grid, suppressor grid and so on, there is no need to give the control grid its full name. The control grid is usually a spiral of wire of constant pitch. The closer the spiral the greater the mutual conductance. In a variable-mu valve, the pitch of the spiral varies along its length.

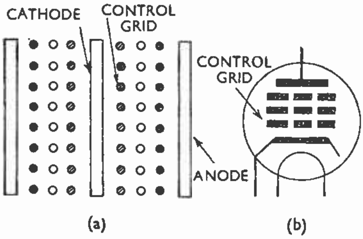


Fig. 48. Diagram of electrodes (*a*) and the usual symbolic representation (*b*) of a pentode, showing the control grid to be that nearest to the cathode.

Associated with the control-grid electrode is the mutual conductance of a hard-vacuum valve, an extremely important quantity (see AMPLIFICATION FACTOR, ANODE SLOPE-CONDUCTANCE, MUTUAL CONDUCTANCE, TRANSCONDUCTANCE).

In class-A amplification, the control grid is biased negatively with respect to cathode and the variation of potential due to the wave applied to the control grid never causes it to have a positive potential with respect to cathode (Fig. 49). In class-B amplification, the control grid does become positive with respect to the cathode, and current flows between it and the cathode.

In a gas-filled triode or tetrode, the grid bias determines the anode voltage at which ionization takes place. Once current flows, the control-grid potential has no effect upon the anode current. See GAS-FILLED TRIODE, GRID BIAS, GRID CURRENT, GRID POTENTIAL, GRID SWEEP, MUTUAL CONDUCTANCE, TRIODE, VARIABLE-MU VALVE.

CONTROLLED-CARRIER MODULATION. Synonym for FLOATING-CARRIER MODULATION.

CONTROLLED SENDER. Sender in which a controlling device is employed to keep the radiated frequency within narrow limits.

CONTROLLED TRANSMITTER. See CONTROLLED SENDER.

CONTROL RATIO. Term used in connexion with a gas-filled triode or tetrode. It is a number expressing the ratio of the anode voltage at which ionization takes place, to the grid voltage existing when the ionization takes place. If a gas-filled triode is not passing current, and the grid has a potential of $-E_g$ volts, then the anode voltage must be raised to E_a volts before current starts to flow. The more negative the grid is made, the more positive E_a must be to start ionization. The ratio E_a/E_g is the control ratio. As will be seen from Fig. 50, it tends to remain constant over a wide range of values. See GAS-FILLED TRIODE, IONIZATION POTENTIAL.

CONTROL ROOM. Room in which all transmission-line links are centralized, and in which switching and fading

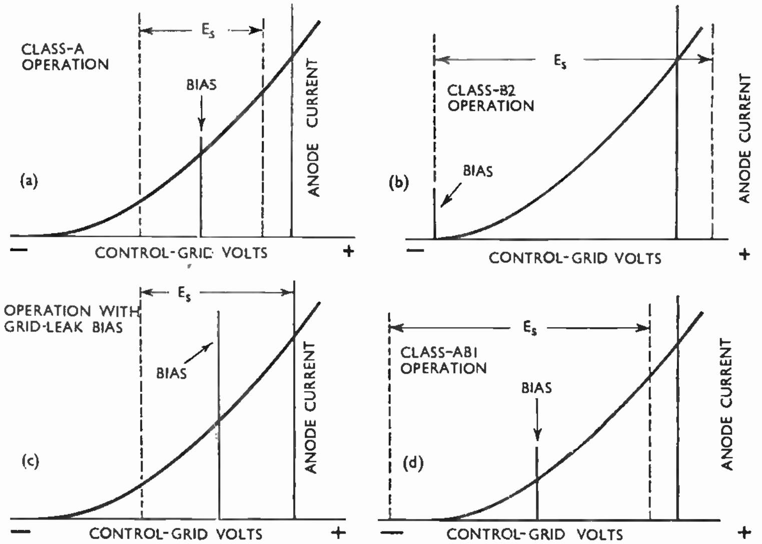


Fig. 49. Grid-volts/anode-current characteristic of an amplifier valve, E_s being the grid sweep: (*a*) with bias for class-A operation; (*b*) the valve biased to cut-off; (*c*) zero bias, the condition for automatic grid-bias using the grid-leak principle, and (*d*) the condition which exists in class-AB1 valve operation.

operations are carried out and the level of the input to the modulation circuits of senders is regulated. The links carry the audio-frequency currents representing the output from the microphone; that is to say, "carrier" systems in which modulated waves are sent through the transmission lines are not used. A diagram of a broadcasting system comprising several senders is shown in Fig. 51. It may be compared with Fig. 31 on page 79 (BROADCASTING) which shows the basic principles of a single-sender system.

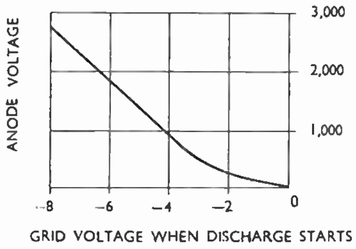
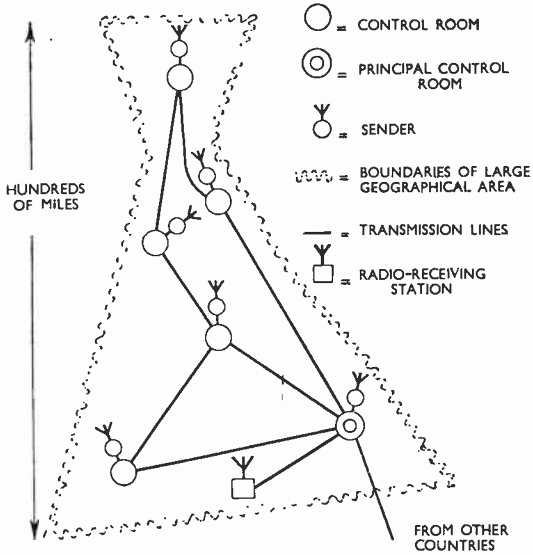


Fig. 50. Graph showing that the control ratio—that is, the ratio of anode voltage to grid voltage at which discharge begins—is constant over a considerable part of the working characteristic of a representative gas-filled triode.

Each control room centralizes the links which join all the control rooms together (Fig. 51) and each control room is at the junction of lines from places in which outside broadcasts are made. Lastly, each control room is connected by a short line to a local sender (Fig. 52). This system, however, is not invariable; cases may arise where a sort of sub-control room in a town or city may not be directly connected to a local sender.

The network of transmission lines makes it possible to route any programme, wherever it takes place in the area, to any sender via its local control room. Lines coming from other countries may be used to accept programmes made in other countries

Fig. 51. Formal diagram showing how a control room forms the junction of lines from and outgoing to other control rooms and to local senders.



or areas, and form part of the public-telephone system. In Britain, the B.B.C. hires local and trunk lines from the Post Office; these trunk lines are specially treated to pass frequencies of up to 8,000 c/s without serious distortion. When the programme to be broadcast is made in another continent, separated from the area considered by a large ocean so that a transmission line cannot be used to convey the programme, a radio link is set up and the receiving end is linked to a principal control room.

Apart from the switching gear, which can be operated in each and every control room to form a flexible system, the function of regulating the level of the audio-frequency currents sent to the local sender is also centralized. A sender has a certain maximum power, and so the power in the modulated wave has a maximum limit which cannot be exceeded without creating harmonic distortion. At the other end of the scale, the power in the modulated wave must exceed a certain minimum, otherwise it will not be sufficiently great to overcome noise (see SIGNAL-TO-NOISE RATIO, SERVICE AREA).

The contrast of volume in orchestral playing might be of the order of 60 to 70 db.; if the average power in the modulated wave coming from a sender fell much more than 30 db. below a (limited) maximum, the noise level would become predominant. Thus a contrast level of 60 db., which represents reality, has to be made into a contrast level of 30 db. when broadcasting gives us its synthesis of music.

To do this, a skilled person must operate a gain control in order to level out the dips and round off the peaks that occur in the microphone output. This function of controlling must be dictated by one person; it is

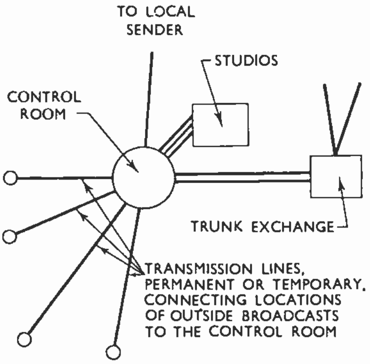


Fig. 52. Schematic diagram of the various lines radiating from the control room of a broadcasting system.

useless to have two with different ideas. This one person is given an apparatus and a position which may be considered as part of the control room.

The control room contains racks to hold the many line amplifiers which are set to raise the level of the power fed into the lines to a value sufficient to overcome noise; or amplifiers which raise the level of incoming signals to a sufficient value. See SIMULTANEOUS BROADCASTING, STUDIO, STUDIO-CONTROL CUBICLE, TRANSMISSION LINE.

CONTROLS. Generic term applied to devices used in an electrical circuit for varying the constants of individual elements, for example, volume control, rheostat, switch.

CONVERSION. Synonym for FREQUENCY-CHANGING.

CONVERSION CONDUCTANCE. Quantity associated with a frequency-changer valve. It is the equivalent of mutual conductance or transconductance for a valve where the frequency of the amplified wave is not changed in the process of amplification. If a wave of a certain voltage and frequency f_1 is applied to one electrode of a frequency-changer valve, then, from another electrode, a current I, alternating at a frequency f_2, can be drawn. The maximum value of this current occurs when the electrode path which completes the circuit has zero resistance.

Conversion conductance is the ratio of the short-circuit current of changed frequency f_2 drawn from one electrode, to the voltage of frequency f_1 applied to the other electrode. This quantity is usually expressed as so many milliamperes per volt. See CONVERSION GAIN, FREQUENCY-CHANGER VALVE, MUTUAL CONDUCTANCE.

CONVERSION DEMODULATION. Synonym for FREQUENCY-CHANGING.

CONVERSION DEMODULATOR. Synonym for FREQUENCY-CHANGER.

CONVERSION DETECTION. Synonym for FREQUENCY-CHANGING.

CONVERSION DETECTOR. Synonym for FREQUENCY-CHANGER.

CONVERSION GAIN. Term used to express the voltage gain of a frequency-changer valve. It is the equivalent of stage gain in an amplifying valve when the frequency of the wave is not changed in the process of amplification. If a voltage E_1 at a frequency f_1 is applied to the input of a frequency-changer and produces at the output a voltage E_2 at a frequency f_2, the ratio of E_2 to E_1 is the conversion gain. See CONVERSION CONDUCTANCE, STAGE GAIN.

CONVERSION RESISTANCE. Reciprocal of CONVERSION CONDUCTANCE (q.v.).

CONVERSION TRANSCONDUCTANCE. Term analogous to MUTUAL CONDUCTANCE (q.v.) but applicable only to frequency-changer valves. Conversion transconductance is given by the current at the difference frequency flowing in the anode circuit, for zero anode load, divided by the signal voltage at the control grid. It is expressed in milliamperes per volt. See FREQUENCY-CHANGER.

CONVERTER. Machine for converting alternating current to direct current, or vice versa. See MOTOR CONVERTER, MOTOR GENERATOR, ROTARY CONVERTER.

COOLED VALVE. Valve which is operated in conjunction with some auxiliary means of cooling. Owing to the generation of heat by electron bombardment, particularly of the anode, it is necessary, when valves handle high power, to provide some extra cooling.

Air and water cooling are used. Air may be blown on to the bulb or on to an exposed anode with fins on it to assist cooling. Water is used to cool the anode by passing it over the surface of the anode. The extra capacitance induced by the air-cooling of a finned anode limits the use of such valves for ultra-high-frequency work. See AIR-COOLED ANODE, AIR-COOLED VALVE, SILICA VALVE, WATER-COOLED VALVE.

CO-PLANAR GRID VALVE. See WUNDERLICH VALVE.

COPPER-OXIDE DETECTOR. Detector using the rectifying properties of copper oxide in contact with copper (see METAL RECTIFIER). Rectifiers of this type may be used for the detection of radio-frequency signals up to frequencies of a few megacycles per second, provided that the physical size of the disc is reduced to the minimum. This is to keep down the self-capacitance between the discs which would otherwise short-circuit the radio-frequency currents.

As the frequency is raised, the by-passing action due to the self-capacitance begins to come into play even with the smallest practicable size of disc (about 2 mm. in diameter). Up to this point, however, the copper-oxide detector is both efficient and stable.

COPPER-OXIDE MODULATOR. Commutator modulator using copper-oxide rectifiers. See COMMUTATION MODULATION, COPPER-OXIDE RECTIFIER, RING MODULATOR.

COPPER-OXIDE RECTIFIER. Form of metal rectifier in which the rectifying action takes place between copper oxide and copper. If the surface of a clean piece of copper is oxidized, then the conduction between the copper and the oxide depends upon the sense in which voltage is applied. This rectifying action is thus between two hidden surfaces, that is to say, that of the clean copper and the inner surface of the covering oxide. The molecular action which causes this asymmetrical conduction is not completely understood, but that it takes place between the underside of the oxide and the clean copper is certain.

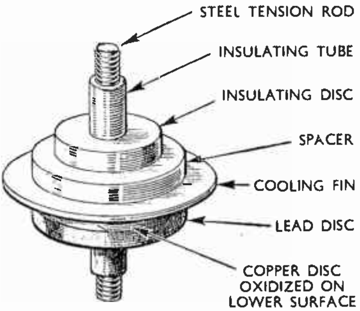


Fig. 53. Assembly details of a copper-oxide rectifier element.

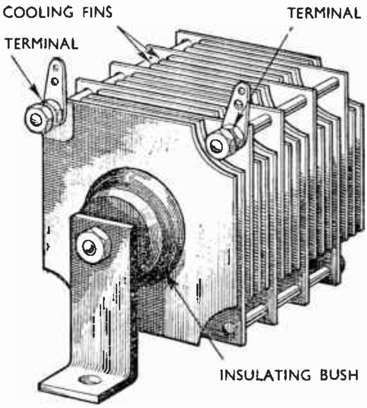


Fig. 54. Typical series-parallel arrangement of copper-oxide-rectifier units incorporating cooling fins.

Contact must be made to the copper on the one hand and the outer surface of the oxide on the other in order to establish the circuit of this rectifier.

Practical advantage of this effect has been taken by constructing rectifiers which can handle a wide range of power, and which, because no chemical action takes place, have a virtually unlimited life.

Fig. 53 illustrates the construction of a typical copper-oxide rectifier, such as is used for rectifying alternating currents in mains units and, in general, for converting alternating to direct current. It will be noted that a lead disc makes contact between the oxidized surface and the terminal of the rectifier.

Fig. 54 shows how the units of Fig. 53 may be assembled with cooling fins to dissipate the heat. This design is essential when power efficiency is important. A series-parallel arrangement is used, that is, a number of units may be in series but the groups made from these units are in parallel.

It is not uncommon to find copper-oxide rectifiers assembled as voltage-doublers, when the application of a single-phase alternating current to one pair of terminals results in a unidirectional current at the other (see VOLTAGE-DOUBLER). The internal impedance of a copper-oxide rectifier is greater for a given output than that of a valve-rectifier system.

Apart from its uses in converting alternating to direct current where considerable power is involved as, for example, with accumulator-charging equipment, the copper-oxide rectifier is made in very small sizes for applications as an instrument rectifier, electronic switch (in the ring modulator) and as a detector in radio receivers. The copper-oxide rectifier is only one form of metal rectifier; the selenium rectifier is another and has basically similar properties. See METAL RECTIFIER, RECTIFIER INSTRUMENT, SELENIUM RECTIFIER.

COPPER WIRE DATA. Details of diameter, cross-sectional area, weight, working current, resistance, turns per inch, etc., applicable to each standard wire-gauge size of copper wire. Information of this nature is to be found from a table appearing in the Reference Section at the end of this book.

CORE. Of an inductor, the space enclosed by the turns of the coil (Fig. 55). Any means of increasing the flux linkages between the turns of a coil increases the inductance of the coil (see INDUCTOR, MAGNETIC FLUX). Thus iron, which has a permeability greater than unity, is frequently placed in the core of a coil, and the inductor is then described as iron-cored.

In order to avoid losses in the iron when the wave frequency is high, the iron may be laminated. For use at radio frequencies, the core is filled with a mixture of iron powder and some insulating "binder" which holds the iron particles firmly in position yet insulates them electrically. This diminishes eddy-current losses in the iron, but leaves the core with a permeability greater than unity. Air cores are used when, even with dust-iron cores, the losses are excessive. See DUST-CORED INDUCTOR, EDDY CURRENT, INDUCTANCE, LAMINATION, PERMEABILITY.

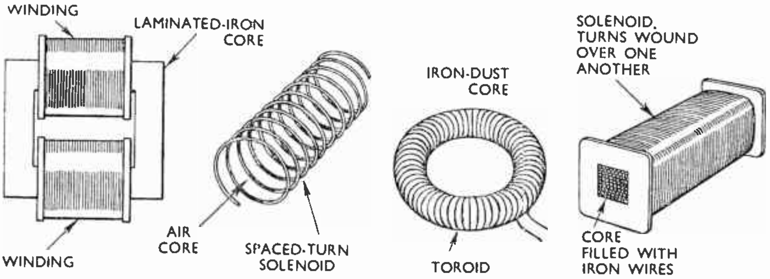


Fig. 55. The core of an inductor is the space enclosed by the turns of the coil; it may be filled by laminations of iron, by iron wires, by an iron-dust composition or by air. An air-cored inductor is generally to be prefered when the inductor is to operate at high radio frequencies and the losses in a ferro-magnetic core may be so great as to reduce rather than increase the Q-factor of the coil.

CORNER REFLECTOR. Device consisting of reflecting plates at right angles to one another designed to return radar pulses along their original path and thus increase the range at which the object incorporating the corner reflector can be detected.

CORONA. Visible discharge of electricity from a conductor into the surrounding air which occurs when the potential gradient at the surface exceeds a certain value, the value being, nevertheless, short of that necessary for a spark. See ATMOSPHERICS.

CORRECTED BEARING. Bearing obtained when the reading obtained experimentally from a direction-finder equipment has been corrected for all known errors.

COSINE CURVE. Synonym for COSINE GRAPH.

COSINE FUNCTION. Quantity or factor related to some other factor in such a way that one is equal to or proportional to the cosine of the other. Thus, A is a cosine function of B if $A = \cos B$.

COSINE GRAPH. Graph obtained by plotting the cosine of an angle against the angle (Fig. 56). It has the same shape as a SINE GRAPH (q.v.) but for angles between zero and 360 deg. begins and ends at unity. In other words, the cosine graph is obtained by displacing the sine graph to the left by 90 deg. An example of the use of the cosine graph is in expressing as an angle the lag or lead of alternating current.

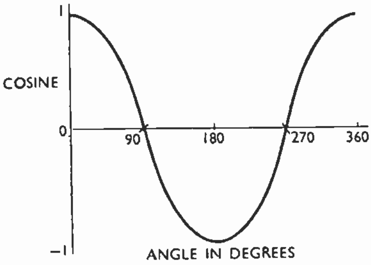


Fig. 56. Cosine graph; the curve is obtained by plotting the cosine of each angle against the angle.

COSINE WAVE. Wave having the form of a COSINE GRAPH (q.v.). The idea of the cosine wave is a useful conception, as the following examples show. If a voltage of cosine wave form is applied to an inductive circuit, the current which flows has a sinusoidal form, and if a voltage of sine wave form is applied to a capacitive circuit, the current has a cosine wave form. See SINE WAVE.

COSMIC NOISE. See ATMOSPHERICS.

COSMIC RAY. Path traversed by waves thought to enter the atmosphere from outer space. Such waves are shorter than gamma rays and have a high degree of penetration.

COULOMB. Practical measure of electrical quantity. It is defined as that quantity of electricity which is delivered by a current of one ampere flowing for one second.

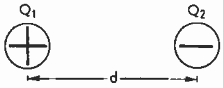


Fig. 57. Coulomb's law states that, where two charges Q_1 and Q_2 are separated by a distance d, the physical force of attraction or repulsion is proportional to the product of Q_1 and Q_2 divided by d squared.

COULOMB'S LAW. One of the basic relationships of electrostatics. It states that the forces of repulsion and attraction, which exist when charged objects are in proximity to each other (Fig. 57), obey the fundamental law of inverse squares; this law states that an electrical force is inversely proportional to the square of the distance between the component charges, and that the attraction or repulsion of these charges is in direct proportion to the product of the values of the charges.

COUNTERPOISE. Arrangement of insulated conductors placed a few feet above the ground and used in conjunction with an aerial system instead of, or as well as, a direct connexion to earth (Fig. 58). The arrangement commonly takes the form of stretched wires running out fanwise, or as a parallel network under the aerial.

COUPLED ADCOCK DIRECTION-FINDER. Adcock direction-finder in

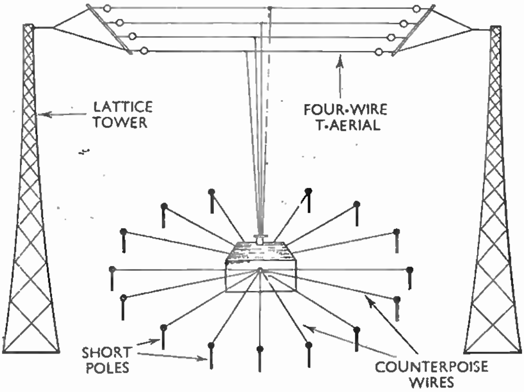


Fig. 58. Radial form of counterpoise or capacitive earth. Wires, only a few of which are shown, radiate from distribution points on each side of the sender building to a ring of short poles.

which signals are transferred from the aerial circuit to the receiver by means of suitably arranged inductive couplings. In this way, the effect of energy picked up by the horizontal portion of the aerial-system is minimized, with the consequent reduction of certain errors. See U-TYPE ADCOCK DIRECTION-FINDER.

COUPLED CIRCUIT. Circuit which receives energy from another circuit by electromagnetic induction (Fig. 59). The term is generally used in a specialized sense; to describe, for instance, the coupling between circuits when there is no metallic connexion. Circuits can be coupled by including a common reactance, resistance or impedance in both circuits.

Another form of coupling is made by using the proximity of two inductors, one in each circuit, to ensure the transfer of energy from one circuit to another. The distinction is, perhaps, too fine, as the mutual inductance in the case of inductive coupling is, in effect, an impedance common to the two circuits. See CAPACITIVE COUPLING, COUPLING, INDUCTIVE COUPLING, RESISTIVE COUPLING.

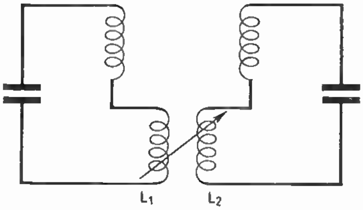


Fig. 59. Example of coupled circuits; mutual inductance between L_1 and L_2 forms the coupling by which energy passes to and fro between the circuits.

COUPLING. The condition in which electrical energy may be transferred from one circuit to another, whether the circuits are physically connected or not. The use of the term varies according to the aspect of the electrical circuits seen by different people in different circumstances. For instance, if transmission problems are considered in terms of filters and networks, the system shown in Fig. 60 is a form of band-pass filter; while from another point of view, the system might well be described as two coupled tuned circuits. Again, a theorist analysing filters would disregard Fig. 60a and redraw it as in Fig. 60b. The term coupling would not be used.

Similarly, from a radio-engineering point of view, the aerial is coupled to the closed circuit in Fig. 60c; but from the more general aspect of transmission, the same diagram might be said to show a transformer, in which the inductive reactance of the leakage inductance is neutralized by the inclusion of a capacitive reactance of opposite sign (Fig. 60d).

Common-impedance coupling (Fig. 61a) implies that an impedance is common to both circuits, so that energy is transferred from one circuit

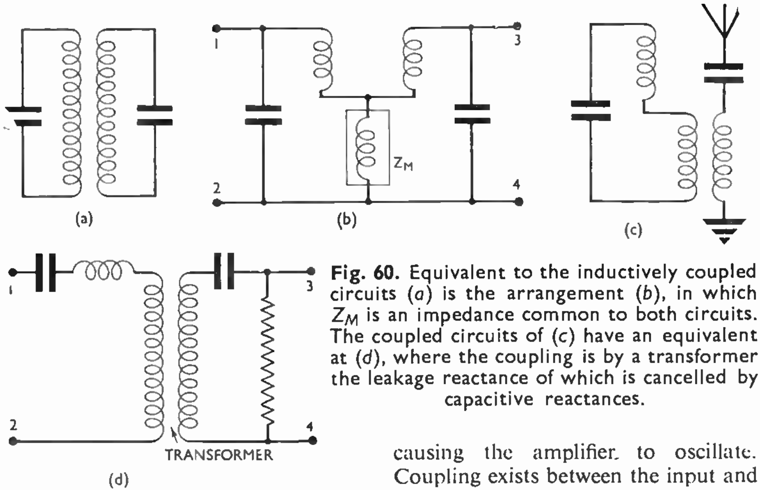
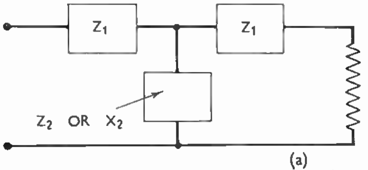


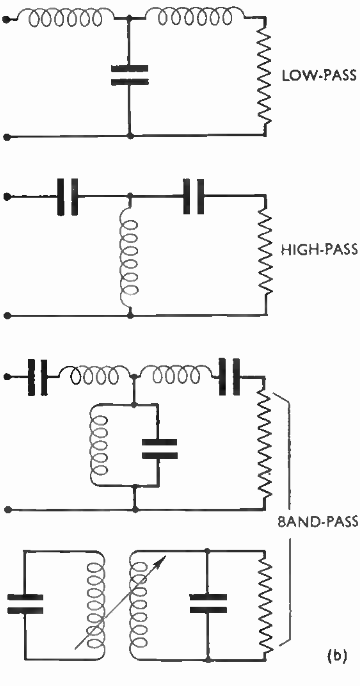
Fig. 60. Equivalent to the inductively coupled circuits (*a*) is the arrangement (*b*), in which Z_M is an impedance common to both circuits. The coupled circuits of (*c*) have an equivalent at (*d*), where the coupling is by a transformer the leakage reactance of which is cancelled by capacitive reactances.

to the other. But each of the circuits shown in Fig. 61b, in which an impedor is replaced by a reactor, are filter circuits. But here, again, by one person they may be described as coupled circuits, by another, as filter circuits. A distinction might be drawn involving the conception that filter elements have to be given exact values if their response characteristics are to conform to a calculated value, whereas "coupling" is conceived in a more casual way.

There can be no argument, however, about the use of the term to describe unwanted interconnexion of circuits. Thus an exposed connexion in the input circuit of a sensitive valve amplifier may pick up energy from an exposed connexion in the output. causing the amplifier to oscillate. Coupling exists between the input and output of the amplifier, just as it may exist between unscreened stages of an amplifier. The oscillators of a beat-



(a)



(b)

Fig. 61. The schematic diagram (*a*) is that of a common-impedance- (or reactance-) coupled circuit. Its exact equivalents (*b*) may, however, be correctly described as filter circuits.

frequency oscillator may be coupled, due to incomplete screening, and, in consequence, tend to cog. In describing such spurious couplings as these, the term seems to have found a common usage.

There is, furthermore, a common use of the term to describe different forms of amplifier, such as "resistance-capacitance coupling," "transformer coupling." See BAND-PASS FILTER, CAPACITIVE COUPLING, CLOSE COUPLING, COMMON-IMPEDANCE COUPLING, COUPLED CIRCUIT, INDUCTIVE COUPLING, LOOSE COUPLING, RESISTIVE COUPLING, TRANSFORMER.

COUPLING CAPACITOR. Capacitor forming a part of a common impedance in coupled circuits (see CAPACITIVE COUPLING); or a blocking capacitor; or, typically, the capacitor in a resistance-capacitance amplifier which prevents the steady voltage component at the anode of one valve affecting the grid bias of the valve in the following stage. See BLOCKING CAPACITOR, CAPACITIVE COUPLING, COUPLING, RESISTANCE-CAPACITANCE AMPLIFIER.

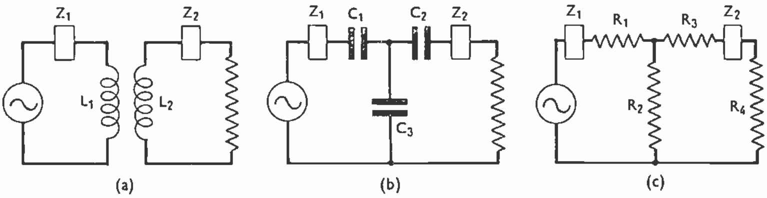


Fig. 62. Coupling coefficients in the above circuits are: (*a*) $M/\sqrt{L_1L_2}$, where M is the mutual inductance of L_1 and L_2; (*b*) $\sqrt{C_1C_2}/\sqrt{(C_1+C_3)(C_2+C_3)}$; and (*c*) $R_2/\sqrt{(R_1+R_2)(R_2+R_3+R_4)}$. Impedances Z_1 and Z_2 do not affect coupling coefficient.

COUPLING COEFFICIENT. Number expressing the closeness, or tightness, of coupling. In general, the term expresses the amount of energy transferred from one circuit to another when the circuits are coupled. In an inductively coupled circuit (Fig. 62), the coefficient is given by $\frac{M}{\sqrt{L_1L_2}}$, M being the mutual inductance, and L_1 and L_2 the inductances in the two circuits which are coupled.

Thus, when $M = \sqrt{L_1L_2}$, the coupling coefficient is unity; if $L_1 = L_2 = L$, then, when $M = L$, the coefficient is unity. As M, the mutual inductance, is reduced so the coupling is not so tight, or is looser. If M is very small, the circuits are loose-coupled; and if large, tight-coupled.

The term applies not only to inductive, but also to capacitive and resistive coupling. The formal definition of the coupling coefficient, to embrace all forms of coupling, is: "the ratio of the mutual- or common-impedance component of two circuits, to the square root of the product of the totals, in the two circuits, of the impedance components of the same kind." The impedances referred to may be preponderantly inductive, capacitive or resistive. See CAPACITIVE COUPLING, COMMON-IMPEDANCE COUPLING, COUPLING, INDUCTIVE COUPLING, RESISTIVE COUPLING.

COUPLING COIL. Term which may be employed to describe either of the coils in a variable mutual-inductance arrangement, sometimes termed a "variometer." The feedback coil of an oscillator, often called the "reaction" or "retroaction" coil, might be called a coupling coil; and the coil used to couple an aerial to the closed circuit of an oscillator could be called a coupling coil. See COUPLING.

COUPLING CONDENSER. Synonym for COUPLING CAPACITOR.

COUPLING FACTOR. Synonym for COUPLING COEFFICIENT.

COUPLING RESISTOR. Resistor which forms the common part of resistive-coupled circuits. See COUPLING COEFFICIENT, RESISTIVE COUPLING.

COUPLING SYSTEM. That part of a coupled circuit in which coupling takes place. See COUPLING.

COURSE-INDICATING BEACON. Automatic radio sender which radiates characteristic signals in one or more distinct directions, for the guidance of ships or aircraft. Such beacons may be arranged to cover a particular route and thus provide navigational assistance from point to point.

COVERAGE. Term, of American origin, for the area covered by strong signals from a broadcasting station, the service from which is defined in terms of its coverage. British usage prefers the synonymous term, SERVICE AREA (q.v.).

c.p.s. Abbreviation sometimes used instead of c/s for CYCLES PER SECOND.

CREST VALUE. Synonym for PEAK VALUE.

CRITICAL ANODE-VOLTAGE. See IONIZATION POTENTIAL.

CRITICAL COUPLING. Smallest degree of coupling existing between two tuned circuits, sufficient to give a just detectable band-pass, as compared with a peak-tuned response curve. Two tuned circuits tightly coupled together give a response curve which is substantially flat over a band of frequencies. Critical coupling is that small value of coupling which makes the band-pass characteristic just begin to flatten over a small band of frequencies. See BAND-PASS FILTER, COUPLING COEFFICIENT, INDUCTIVE COUPLING.

CRITICAL DISTANCE. Distance between the screen-grid and anode electrode of a tetrode which, when correct, ensures that the effects of secondary emission are nullified.

CRITICAL FREQUENCY. Highest frequency that an ionospheric layer can reflect to earth when the ray enters the layer at vertical incidence. The maximum electron density of an ionospheric layer is usually expressed in terms of the critical frequency, and if this frequency is determined, it is possible to estimate with a fair degree of accuracy the best short wavelengths to use for reliable long-distance communication between any two points.

The critical frequency is higher during the day than at night, and lower during the winter than in summer. Because of these characteristics, it is possible to use much shorter wavelengths during the day than at night. For instance, a communication over a distance of 6,000 miles during the daytime could be effected with a wavelength of 14 or 15 metres; but at night it might be necessary to use a wavelength as long as 30 metres. See IONOSPHERE, IONOSPHERIC RAY, IONOSPHERIC REFLECTION, IONOSPHERIC REFRACTION.

CRITICAL GRID-VOLTAGE. Value of the grid voltage in a gas-filled triode at which grid current just starts to flow, the potential of other electrodes being specified. See GAS-FILLED TRIODE.

CROSSED-DIPOLE AERIAL. System of two or more horizontal half-wave dipoles, set at right-angles, with each pair or group symmetrically disposed about a centre point. The system may be used in conjunction with a goniometer, in a similar manner to the crossed loops of the Bellini-Tosi direction-finder, for work on the higher frequencies. See BELLINI-TOSI DIRECTION-FINDER.

CROSS-MODULATION. Modulation of the carrier of a wanted signal by an unwanted, or interfering signal. In any communication system designed to transmit several messages simultaneously, we may, in considering the clear transmission of one message, call this message the "wanted" message or signal. In other words, it is necessary that each message shall be transmitted independently of all the others. It is undesirable, for instance, in a public telephone system that a person intended to receive one message shall hear another. Thus any one message or signal is the wanted signal or message, and any other, with respect to this wanted signal, is "unwanted."

An understanding of cross-modulation can be gained from the dynamic characteristic of a valve amplifier (Fig. 63). Consider two waves of different frequencies added together and applied to the grid. When the feebler wave is "riding" on the stronger, it is applied to the steep or the shallow parts of the dynamic characteristic depending on the instantaneous value of the stronger signal. Thus the weak signal is alternately subjected to low and high amplification. This is the mechanism of non-linear modulation, by which the stronger wave modulates the amplitude of the other (see NON-LINEAR MODULATION).

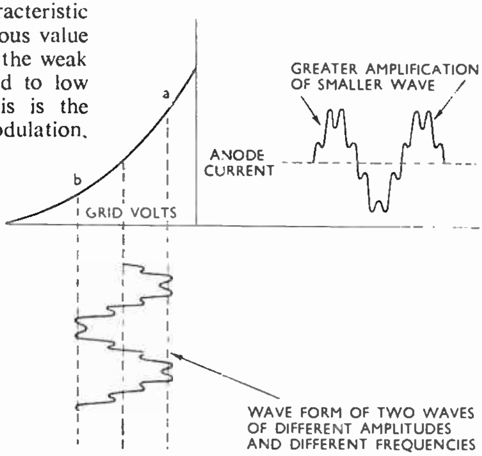


Fig. 63. Cross-modulation results when the wave which is produced by adding the voltages of two waves is applied to the grid of an amplifier valve. When working over a part *a* of the dynamic characteristic, amplification of the smaller-amplitude wave is greater than when working over the less steep part *b* of the characteristic.

In normal modulated carrier-wave transmission over lines, several messages are carried by carrier waves of different frequency. These waves are all grouped together in one conductor and pass, within a wide frequency band, through amplifiers or repeaters. Non-linear response of such amplifier will cause cross-modulation and it is usual to employ a very large amount of negative feedback in repeaters to reduce such effects. See CARRIER, GROUP MODULATION, MODULATED AMPLIFIER.

CROSSTALK. In a multi-pair cable, the induction of signals in one circuit from a neighbouring circuit; in a carrier system, the interference between two channels caused by intermodulation.

Numerous precautions are taken in the construction of a multi-pair cable to minimize crosstalk; for example, each pair of conductors is twisted and balanced and the power fed to each circuit is limited to a few milliwatts. Any faults which cause unbalance or excessive power may result in crosstalk.

The mechanism causing crosstalk in carrier systems is different. Repeaters are used to amplify several signals simultaneously, each signal consisting of a modulated carrier wave. If any one signal is large enough to drive the repeater off the linear part of its characteristic, rectification occurs and the modulation of one carrier is, in effect, transferred to other carriers. To minimize this cross-modulation the repeaters must have great linearity; this is achieved by the use of a high degree of negative feedback. See BALANCED TRANSMISSION LINE, SIMULTANEOUS BROADCASTING.

CROSSTALK ATTENUATION Attenuation between the sending terminals of the circuit causing crosstalk and the receiving terminals of the circuit in which crosstalk is caused. The attenuation can be measured directly by a volume indicator and expressed in decibels if the two pairs of terminals have the same impedance; but, if the impedances differ, a correction must be applied before the attenuation can be correctly stated.

Crosstalk volume cannot be evaluated from crosstalk attenuation unless the volume on the circuit causing the crosstalk is known. See CROSSTALK, CROSSTALK VOLUME.

CROSSTALK FACTOR. Ratio of the depth of modulation of the crosstalk in a second carrier to the depth of modulation of the first carrier when the modulation on a carrier is transferred by cross-modulation to a second carrier. See CROSSTALK.

CROSSTALK VOLUME. Volume of crosstalk speech expressed in decibels with respect to Reference Telephonic Power. See CROSSTALK, REFERENCE TELEPHONIC POWER, S.F.E.R.T. VOLUME INDICATOR.

C.R.T. Abbreviation for CATHODE-RAY TUBE.

CRYSTAL DETECTOR. Detector using the non-linear conductivity of certain crystals placed in contact with each other, or in contact with a suitable metal. Such contacts permit current to flow across the junction more readily in one direction than in the other, so that the arrangement acts as a rectifier and may thus be used for the detection of radio-frequency signals.

Examples of crystal-to-metal contacts are the galena and carborundum detectors. The former uses a crystal of galena in association with a light spring of copper or brass, as shown in Fig. 64. The sensitivity varies considerably with the actual spot on the crystal and with the pressure, so that frequent adjustment of the "cat's whisker," as it is called, is necessary.

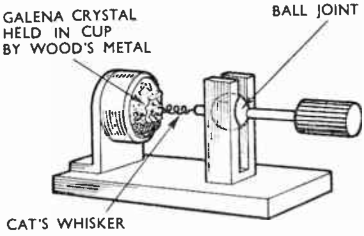


Fig. 64. Crystal detector comprising an adjustable spring of copper or brass in contact with galena crystal.

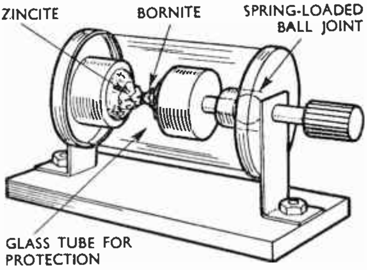


Fig. 65. Perikon detector, in which a spring-loaded bornite crystal is held in contact with a zincite crystal.

An alternative crystal-to-metal contact is the carborundum-steel arrangement (see CARBORUNDUM DETECTOR), which is not so sensitive as the galena crystal, but is more stable mechanically.

An example of the crystal-to-crystal contact is the zincite-bornite combination known as the Perikon detector. Here again the action is dependent upon finding the right points of contact, and the sensitivity is also dependent upon the pressure, so that one of the crystals is usually mounted in a spring-loaded holder (Fig. 65). A characteristic of a Perikon detector is illustrated in Fig. 66.

CRYSTAL DRIVE. See CRYSTAL-OSCILLATOR DRIVE.

CRYSTAL FILTER. Filter in which certain of the elements or arms of the filter are formed by quartz crystals. A quartz crystal is the equivalent of a series-tuned resonant circuit; it has a low resistance to waves of one frequency and a comparatively high reactance to waves of other frequencies. The notable point is that the crystal is equivalent to a series-tuned circuit with an inductor having a very large Q-factor. See QUARTZ CRYSTAL.

Certain filters give a more nearly ideal performance, as their elements are more like pure reactances; they absorb no power from currents passing through them. Thus a crystal is like a series combination of inductor and capacitor with very large Q-factors, and can be used with advantage in a filter for that reason. The practice of using crystal filters is expensive, and is only justified when the filter is required to give a very large attenuation for waves of certain frequency. See FILTER, Q-FACTOR.

CRYSTAL-GATE RECEIVER. Superheterodyne receiver of extremely high selectivity, this quality being due to the introduction of a quartz-crystal resonator at some suitable point in the intermediate-frequency amplifying circuits, usually in the second-detector grid circuit.

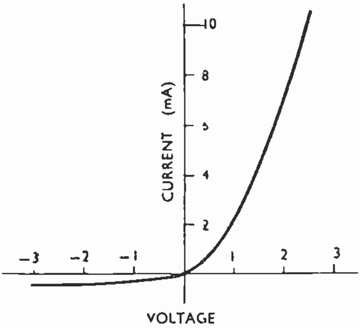


Fig. 66. Voltage/current characteristic of the zincite-bornite type of crystal detector shown in Fig. 65.

The quartz crystal is cut to the exact intermediate frequency, and its extremely sharp resonance properties cause it to act as a narrow "gate," excluding frequencies differing by only small amounts from the true intermediate frequency. Considerable attenuation of the sidebands of a type A3 transmission may result, calling for a suitable rising characteristic in the audio-frequency amplifying circuits.

CRYSTAL HEADPHONE. Headphone with a diaphragm actuated by the expansion and contraction of a crystal plate or pair of plates, such expansion and contraction being caused by the application of electric potentials from a receiver or amplifier. See CRYSTAL MICROPHONE, HEADPHONE, PIEZO-ELECTRIC EFFECT.

CRYSTAL LOUDSPEAKER. Loudspeaker operating on the same principles as the crystal headphone. See CRYSTAL HEADPHONE, CRYSTAL MICROPHONE, LOUDSPEAKER, PIEZO-ELECTRIC EFFECT.

CRYSTAL MICROPHONE. Microphone which depends for its action upon the piezo-electric effect of certain crystals. The crystals used in microphones are generally of Rochelle salt because this exhibits the piezo-electric effect to a greater degree than quartz and other crystals.

If a slice of Rochelle salt is placed between two conducting plates, it will expand or contract, depending on the type of crystal, when potentials are applied between the plates. If an expanding type and a contracting type of crystal are rigidly cemented together, the combination, known as a *bimorph*, will twist or bend when potentials are applied to the plates. Conversely, if the bimorph is bent or twisted, e.m.f.s are developed between the plates. Both bending and twisting types of bimorph are used in crystal microphones.

In one type of crystal microphone a crystal slice is held at three corners, and the centre of a diaphragm is attached by a short reed to the fourth corner (Fig. 67). Thus any movement of the diaphragm caused by sound waves is communicated to the crystal, giving rise to a reciprocating motion of the corner, and alternating e.m.f.s are generated between the plates.

This type of microphone suffers from a number of defects because, to give a reasonably large output, the diaphragm must be at least two or three inches in diameter and its size is thus comparable with the wavelength of high-frequency sound waves. Such a diaphragm offers an impedance to the passage of high-frequency sound waves and may be likened to a breakwater which prevents the passage of sea waves. This "obstruction effect" causes the waves to exert more pressure than if the diaphragm were absent, the microphone tending to give an output which increases with increase in frequency.

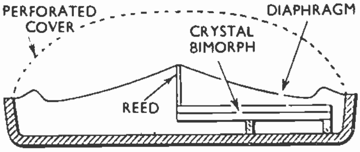


Fig. 67. Form of crystal microphone, shown in section, in which a crystal slice, held at three corners, has its fourth corner attached by a short reed to the centre of the diaphragm.

The diaphragm also causes the microphone to have a poor response to those high-frequency sound waves that strike the instrument at oblique angles of incidence, the response to low-frequency sounds being more or less independent of the angle of incidence. This tends to counteract the obstruction effect but also makes the microphone somewhat directional.

This type of microphone is very useful where the highest possible quality is not required and where the increased output due to use of a diaphragm is an advantage.

In another type of crystal microphone, two bimorphs of the bending type are mounted back-to-back to form a unit, known as a sound cell, which generates e.m.f.s when subjected to pressure (Fig. 68). If the pressures are alternating, as in sound waves, alternating e.m.f.s of the same frequency as the sound wave are generated between the plates. Thus the simplest type of crystal microphone may consist of a single sound cell which is mounted within a protective perforated cover.

No diaphragm is necessary and the dimensions of a sound cell can be made small enough to avoid the defects commonly experienced with microphones which have diaphragms. The output of such a microphone, though free from distortion, is very small; if a larger output is required, however, a number of sound cells may be connected in series or in parallel.

Over the audio range the impedance of a crystal microphone is predominantly capacitive and varies greatly with frequency. For this reason, matching transformers cannot be used to convey the microphone output to the following amplifier; it is usual, therefore, to connect the output of the microphone directly in the grid circuit of the first valve.

The impedance of a single-cell microphone is extremely high and the capacitance of even a short microphone cable would cause a serious loss in the already small output. Thus it is customary to eliminate almost completely the output lead by mounting the microphone amplifier, or the first stage of it, only a few inches from the microphone. The amplifier is then known as a head amplifier and is often housed in a tubular casing built into the microphone stand.

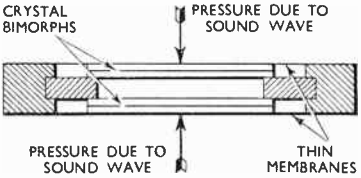


Fig. 68. Section through the type of crystal microphone in which there is a sound cell comprising two bending bimorphs mounted back-to-back.

A multi-cell microphone has a lower impedance and a greater output than a single-cell type and may be used successfully with cables many feet in length. See MICROPHONE, PIEZO-ELECTRIC EFFECT.

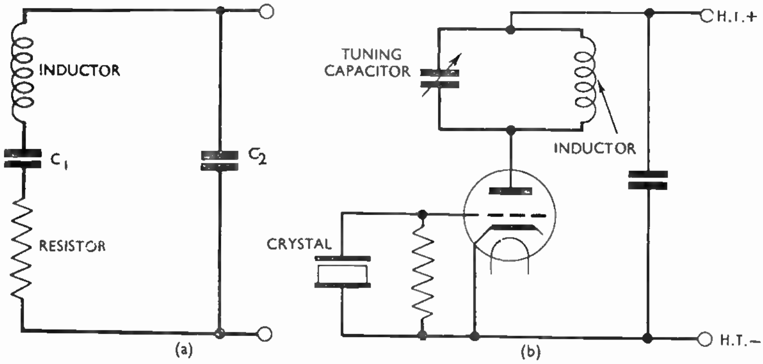


Fig. 69. In a crystal oscillator the frequency-determining element, having the equivalent tuned electrical circuit shown at (*a*), is a vibrating quartz crystal. The circuit diagram (*b*) is that of a simple form of crystal oscillator.

CRYSTAL OSCILLATOR. Term applied to a valve-maintained oscillating system in which the frequency-determining element is a quartz crystal.

The vibrating crystal in its mounting is equivalent to the tuned electrical circuit shown at Fig. 69a. In this circuit, the inductor, the capacitor C_1 and the resistor represent the equivalent mass, compliance (the reciprocal of stiffness) and frictional loss, respectively, of the vibrating crystal. C_2 represents capacitance of the holder.

The equivalent circuit has a frequency of parallel resonance, also one of series resonance. The Q value of the circuit is generally very high.

There are many varieties of crystal oscillator circuits, some utilizing the parallel resonance of the crystal, others the series resonance. A simple circuit is shown in Fig. 69b. Here the crystal replaces the normal tuned-grid circuit of a tuned-anode-tuned-grid oscillator, and operates very close to the parallel resonant condition of the crystal.

In order that continuous oscillations be maintained, it is necessary that there shall be a feedback of energy from the anode circuit to the grid circuit of such phase and magnitude as to meet the damping losses of the crystal and associated components. This implies that there must be a negative-resistance component in the input impedance of the valve, a condition which is obtained by tuning the anode circuit to a frequency slightly higher than that of the crystal.

The frequency stability of a crystal oscillator is much higher than that of normal tuned-circuit oscillators, even without temperature control. For frequency stability of very high order, it is usual to fit the crystal in a thermostatically controlled heat chamber and to employ stabilized supplies. See PIEZO-ELECTRIC EFFECT, QUARTZ CRYSTAL.

CRYSTAL-OSCILLATOR DRIVE. Master oscillator, suitable for controlling a chain of R.F. amplifiers, and in which the frequency-determining element is a piezo-electric crystal. The drive equipment usually includes a limiter stage which keeps the oscillator amplitude low to preserve a good wave form, and a buffer or separator stage which isolates the oscillator proper from the drive output circuit so that the oscillator frequency is not affected by connecting the drive equipment to the sender or any other circuits. See BUFFER STAGE, LIMITER

CRYSTAL OVEN. Temperature-controlled heat chamber containing a piezo-electric crystal. By maintaining the crystal within very close limits of temperature, a high degree of frequency stability is obtained.

CRYSTAL RECEIVER. Radio receiving equipment in which the function of detection is performed by the rectifying property of a light contact on the surface of a crystalline mineral substance (see CRYSTAL DETECTOR).

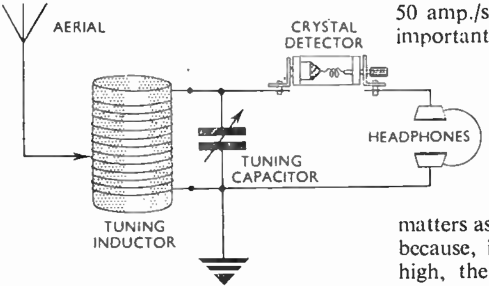


Fig. 70. Circuit connexions of a simple form of crystal receiver suitable for the reception, on headphones, of a local broadcast sender.

Such receivers, much used before thermionic valves were introduced, are usually simple in design, using only one or, at most, two tuned circuits, and consequently are of comparatively low selectivity. Lacking the amplifying power of the valve, they are suitable only for use at relatively short distances from the sender; but, for local reception on headphones where high selectivity is not needed, they are still the cheapest and simplest form of receiver. Fig. 70 shows the circuit of a typical crystal receiver.

CRYSTAL RECTIFIER. See CRYSTAL DETECTOR.

CRYSTAL SET. Synonym for CRYSTAL RECEIVER.

CRYSTAL TELEPHONE. See CRYSTAL HEADPHONE.

c/s. Abbreviation for CYCLE(S) PER SECOND.

C-SERVICE AREA. Area surrounding a broadcast sender in which the field strength is between 2·5 and 5 mV per metre.

CURRENT. See ELECTRIC CURRENT.

CURRENT DENSITY. Measure of current intensity in relation to the cross-sectional area of the conductor in which the current is flowing. Current density is commonly expressed in amperes per square inch. For example, if a current of 5 amp. flows in a conductor having a cross-sectional area of a tenth of a square inch, this is equivalent to a current density of 50 amp./sq. in. Current density is an important factor in deciding such matters as the diameter of a conductor because, if the current density is too high, the conductor may be heated excessively. Thus, to keep the temperature rise within specified limits, the current density must be kept below a certain value.

CURRENT-FED AERIAL. Aerial in which the driving energy is introduced at a current-maximum point, such as the centre of a half-wave dipole; hence the alternative term *centre-fed* aerial. See VOLTAGE-FED AERIAL.

CURRENT FEEDBACK. Negative feedback in which the voltage fed back to the input of the amplifier is directly proportional to the current in the load. Such a circuit arrangement is extensively used in the design of electronic amplifiers to obtain low harmonic distortion, improved frequency response and greater constancy of amplification with change in the supply voltages.

The basic circuit for providing current feedback is that illustrated in Fig. 71. A small resistor is connected in series with the load, and the p.d. developed across it is returned to the input of the amplifier. Here it is connected in series with, but so as to oppose in phase, the normal signal input of the amplifier. The effects of current feedback on gain and distor-

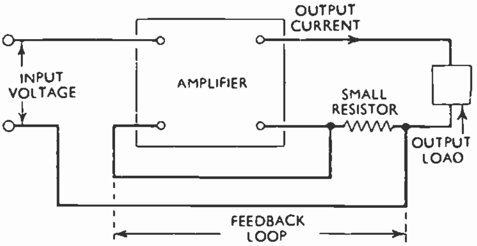


Fig. 71. Schematic diagram of the basic circuit for the provision of current feedback, showing what may be regarded as the feedback loop.

tion are similar to those of VOLTAGE FEEDBACK (q.v.), but its effect on output impedance is different.

When current feedback is applied to a single valve, as it usually is, it increases the output impedance, that is to say, it tends to make a triode behave as a pentode. Consider, for instance, the circuit shown in Fig. 72, where the negative feedback results merely from the omission of the customary by-pass capacitor across the bias resistor *R*; the voltage fed back to the grid will obviously be proportional to the amplitude of the signal current through *R*, which is in fact the anode current.

Suppose now that some change occurs in the anode load. If the load resistance increases, the signal current through *R* will diminish, and so will the voltage fed back to the grid circuit. Since the feedback is negative, its reduction will lead to an increased grid input and so tend to counteract the effect of raising the load resistance by keeping the anode-circuit signal current constant.

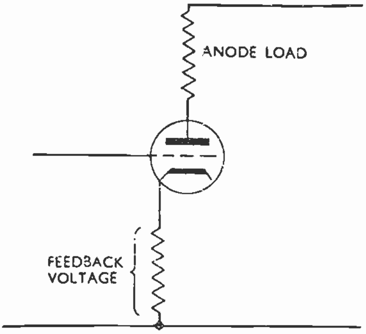


Fig. 72. Current feedback applied to a triode; when the usual by-pass capacitor across the bias resistor is omitted, the result is negative feedback proportional to the amplitude of the current that is flowing in the resistor.

If the anode load is *reduced*, the alteration in the feedback effect will oppose the change of signal current in the anode circuit. Thus changes in the anode load resistance have less effect on the amplitude of the signal currents than they would have in the absence of feedback. The effect is much as though the valve impedance had been considerably increased.

If applied to an output stage, current feedback would exaggerate the attenuation distortion occurring at the frequencies of mechanical resonance, and it is customary, therefore, to restrict its use to so-called voltage-amplifying stages where the increase in output impedance is of no consequence.

In the circuit of Fig. 72 the resistor *R* provides grid bias in addition to current feedback, and, if the value of the resistor is chosen to give correct bias, the current feedback is fixed. It is often desirable to have more or less current feedback than is provided by the bias resistor, and Figs. 73a and 73b show how this can be obtained.

In Fig. 73a the grid circuit is returned to the junction of R_1 and R_2, and the steady potential between grid and cathode is equal to the product of the anode current and R_1, which is therefore the bias resistor. Current feedback is, however, caused by the A.C. component of the anode current in flowing through R_1 and R_2, which together can be termed the feedback resistor. For example, if a cathode resistor of 5,000 ohms is necessary for feedback purposes, and if the bias-resistor value is 1,500 ohms, both requirements can be met by making R_1 equal to 1,500 ohms and R_2 equal to 3,500 ohms.

In Fig. 73b R_1 and R_2 in series determine the grid bias, since the steady potential difference between grid and cathode is due to the anode current in flowing through them. R_1 is shunted by a capacitor C_1, which is chosen to have a very low reactance over the frequency range of the amplifier. Thus the impedance of R_1 and C_1 in parallel is very small and the p.d. developed across them by the A.C. component of the anode current is very small; in other words, R_1C_1 produce negligible feedback. Only R_2 therefore is effective in providing current feedback.

As a numerical example, if the bias-resistor value is 1,500 ohms and only 1,000 ohms are necessary to provide the required current feedback, R_1 should be 500 ohms and R_2 1,000 ohms.

If the full gain of an amplifier is not always required, it is advantageous to "use up" the excess gain as feedback, since by this means distortion, hum, noise, etc., are reduced to their lowest possible level for a given output. This can be achieved by making the feedback variable and setting the gain to the desired value by adjustment of the feedback control. In this way feedback is always at a maximum and distortion at a minimum.

Fig. 73c shows one method of obtaining variable current feedback. This circuit is similar to that of diagram (a) in that R_1 provides bias and $R_1 + R_2$ provide feedback but the secondary winding of the input transformer is returned to the slider of the feedback control R_4. When the slider is at earth potential, circuits (a) and (c) are similar, feedback is a maximum and gain a minimum. At the opposite extreme of its travel, feedback is zero and gain the maximum that the valve can deliver. Between these extremes, intermediate degrees of feedback and gain are obtained.

It is not usually possible, by this means, to obtain more than about 30 db. variation in gain because this is approximately the maximum degree of feedback obtainable with a single valve. But 30 db. of variation is insufficient for many purposes, and often the feedback control is ganged with a conventional gain control in, say, the grid circuit of the following valve. The

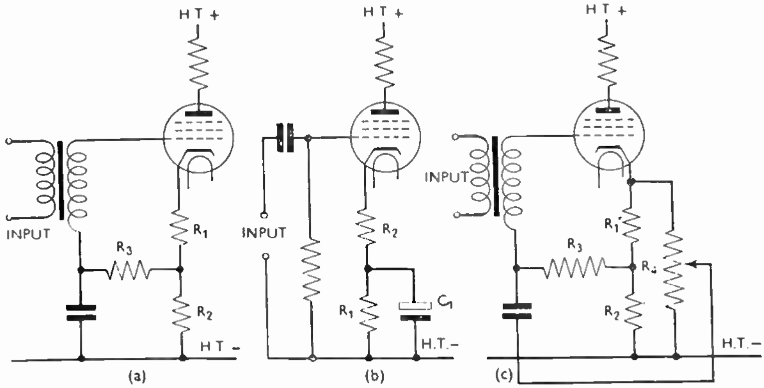


Fig. 73. Circuits which illustrate methods of obtaining (*a*) more current feedback and (*b*) less current feedback than is given by the bias resistor. The third arrangement, illustrated at (*c*), provides variable current feedback.

arrangement is such that, to increase gain from zero, the composite control first advances the grid potential divider to its maximum, the feedback remaining constant at its maximum value, after which continued rotation of composite control reduces the feedback to zero to give maximum gain.

By use of reactances in the feedback chain, it is possible to alter the frequency response of an amplifier to conform to a desired shape. Often, for example, a slight bass lift or treble lift is obtained by means of feedback to offset losses in bass and treble occurring elsewhere in the amplifier.

Top lift can be obtained very simply by connecting a capacitor in parallel with the feedback resistor, the value of the capacitor being chosen so that its reactance is comparable with the value of the resistor at high frequencies. If a larger capacitor is used the effect becomes a loss at the lower end of the amplifier pass-band, and if a very large capacitor is used the feedback is removed entirely, and the amplifier gives maximum gain at all frequencies.

Bass lift can be obtained by connecting an inductor in parallel with the feedback resistor, the inductance being chosen so that its reactance at low frequencies is comparable with the value of the feedback resistor. This is not a good method to use with a valve amplifying very small audio signals because hum may be introduced into the cathode circuit of the valve by induction in the inductor core. The amount of top lift or bass lift obtainable with these two circuits is, of course, limited by the amount of feedback used; if the feedback reduces the gain by 10 db. the maximum lift obtainable is 10 db.

CURRENT TRANSFORMER. Transformer used to measure or register current flowing in a circuit without disturbing the circuit conditions. Three uses of a transformer are shown in Fig. 74; in (a), the turns ratio is chosen so that maximum power is transferred from one circuit to another. If there is no loss, only the voltage and current values are changed between the two circuits, the product of current and voltage being the same on both sides of the transformer.

Fig. 74b shows a voltage transformer, so-called because secondary voltage is greater than the primary; in this case, there is no secondary load, therefore no secondary current and no transfer of power. A transformer-coupled amplifier uses voltage transformers.

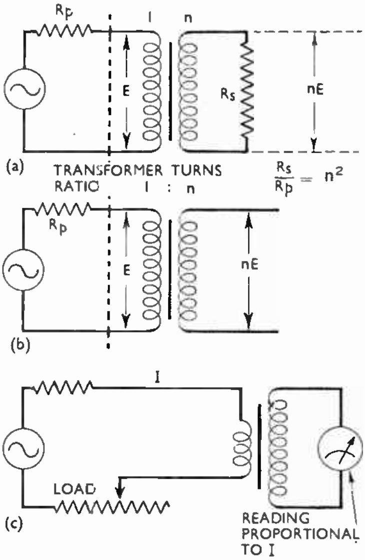


Fig. 74. Functions of the transformer: in (*a*) power is passed from a source to a load (of resistance R_s): (*b*), with load omitted, shows a voltage transformer, and (*c*) a current transformer.

In Fig. 74c, matching does not take place and the current in the circuit is substantially unaffected by the series connexion of the primary of the transformer. It may be assumed that the instrument connected across the secondary of the transformer absorbs negligible power, but it does indicate a current which is proportional to the primary current. The primary current is almost wholly determined by the

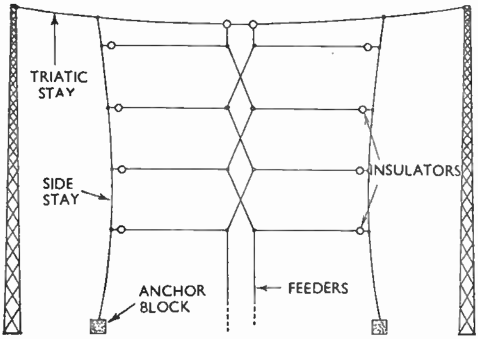


Fig. 75. Simplified representation of an elementary form of curtain array hung from a triatic stay between two masts. The aerial proper consists of four centre-fed half-wave dipoles arranged in a vertical tier

load impedance and is measured by the current transformer. See TRANSFORMER.

CURTAIN ARRAY. Aerial-array consisting of a system of stretched-wire elements, hung between suspension members also made of wire or cable. In a typical form, the whole assembly is hung from a triatic stay between two masts or towers (Fig. 75). It may be backed with a second curtain consisting of passive aerials acting as reflectors to increase the directive properties of the active curtain. This arrangement is valuable on the higher frequencies, when the aerial elements commonly take the form of half-wave dipoles.

CURVE. Synonym for GRAPH.

CUT-OFF BIAS. Grid or modulator-electrode bias voltage required to reduce the anode current of a valve or the beam current of a cathode-ray tube to a negligible value, the potentials of the other electrodes being specified. The term must not be defined as the control-grid bias at which the anode current is zero, because this would be indefinite; for example, the anode current might be zero for a grid bias between 10 and 20 volts negative. See BIAS, CONTROL GRID.

CUT-OFF FREQUENCY. Term used to denote the frequency of the wave at which the attenuation of an ideal filter is zero, but at which an infinitesimal increase or decrease of frequency of the wave causes its attenuation to be finite. Fig. 76a illustrates the meaning of cut-off frequency for a low-pass filter; a band-pass filter has two cut-off frequencies.

The illustration shows attenuation curves of an ideal filter, which uses ideal elements having zero resistance. Assuming the filter elements have zero loss and that the filter is terminated in its image impedance, it can

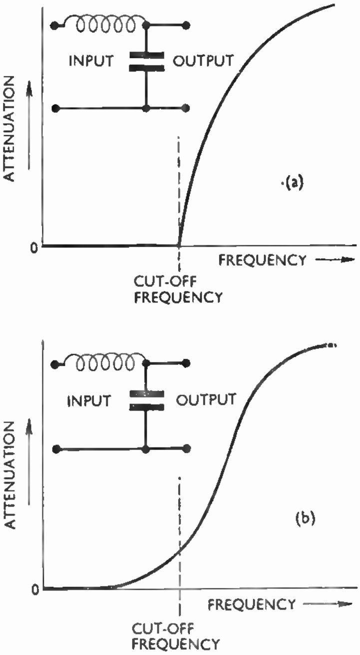


Fig. 76. Attenuation/frequency characteristic curves for filters terminated in their image impedances; (*a*) is that of a theoretical filter with elements having no loss. In practice the rate of change of attenuation at the cut-off frequency is gradual, as in (*b*).

be shown that the attentuation of the filter changes abruptly with frequency from zero to a finite value.

In practice, this does not happen; instead, there is a gradual change in attenuation with frequency around the cut-off frequency (Fig. 76b) because the filter elements are not pure reactances and because the filter cannot be ideally terminated. Nevertheless, the cut-off frequency is an extremely important parameter of a filter, since it is used in making calculations to determine the correct relative values of the filter elements. In other words, the cut-off frequency is a quantity relating the constants of the filter, and forms one of the bases for filter design. The attenuation at the cut-off frequency may be quite considerable, but allowances are made for this in design. See FILTER.

C.W. Abbreviation for continuous wave. See TYPE AO WAVE.

CYCLE. One complete positive, and one complete negative, alternation of a current or voltage. If a simple loop of wire is rotated in a fixed magnetic field, the voltage output across the ends of the loop starts from zero, and gradually builds up in one direction until it reaches a maximum; it then falls back to zero, again builds up to a maximum in the opposite direction, and finally returns to zero. Thus one cycle of alternating voltage is generated in each complete revolution of the simple loop.

The currents and voltages in an oscillatory circuit vary in a similar manner; the frequency, or number of cycles per second, depending on the inductance and capacitance values present in the circuit. If the oscillatory circuit is coupled to a radiating aerial-system it is found that the electric and magnetic fields associated with the radiated wave also vary in a cyclical manner. The electric field builds up to a maximum in one direction, then decays to zero, builds up to a maximum in the opposite direction and finally returns to zero again. See ALTERNATING CURRENT, OSCILLATING CURRENT, WAVE, WAVELENGTH.

CYCLES PER SECOND. Standard unit of frequency expressing the number of repetitions of an alternating voltage or current which takes place in an electric circuit during a period of one second. Convenient multiples of the unit have been evolved for the measurement of electromagnetic-wave frequencies; thus the frequencies of medium- and long-wave radio sending stations are expressed in kilocycles per second, a unit equal to 1,000 c/s; and megacycles per second, equal to 1,000,000 c/s are used to evaluate wavelengths that are shorter than 100 metres.

CYCLOTRON. Machine in which R.F. energy is used to separate electrically charged particles according to their mass. It is practically the only method of separating isotopes, and is used in preparing the uranium isotope from which atomic energy is obtained.

CYLINDRICAL AERIAL. Aerial, designed to cover a considerable band of frequencies, consisting of a half-wave dipole in which each element is composed of a cage. See CAGE AERIAL.

D

D.A.G.C. Abbreviation for delayed automatic gain-control. See DELAYED A.G.C.

DAMPED OSCILLATIONS. Oscillations of which the amplitude progressively decreases with time, as shown in Fig. 1. They may occur in a mechanical system, such as a pendulum, or in an electrical circuit, for example, oscillations produced in a resonant circuit by a spark discharge. See OSCILLATION.

DAMPED WAVES. See TYPE B WAVE.

DAMPING. That property of a circuit which tends to cause decay in the amplitude of oscillation. Examples are friction and viscosity in mechanical systems, and resistance in electrical circuits. If no energy is supplied to the system, the oscillation dies away at a rate dependent on the degree of damping. Damping reduces the sharpness of resonance of tuned systems and slightly decreases the natural frequency of parallel-tuned circuits.

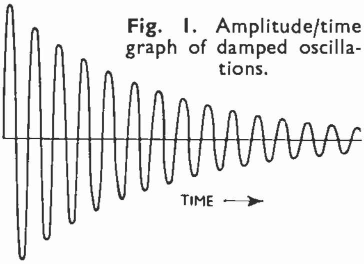


Fig. 1. Amplitude/time graph of damped oscillations.

DAMPING COEFFICIENT. Logarithmic decrement of an oscillation divided by the periodic time (see LOGARITHMIC DECREMENT). It is sometimes called the decay factor.

DARK CURRENT. Current passed by a photocell when no light falls upon it. If the cell is connected, as shown in Fig. 2, with a resistor to limit the current flow and safeguard the cell, it can be shown that a certain amount of current will pass through the cell, even with all light excluded, and this is known as dark current.

DARK RESISTANCE. Resistance of a cell measured under dark conditions, that is to say, with only dark current flowing. See DARK CURRENT.

DASH-POT. Device for preventing the sudden, rapid, or oscillatory motion of any moving part of a piece of apparatus. It has the form of a piston in a closed cylinder filled with air or oil. One part is fixed and the other attached to the moving part of the apparatus. The dash-pot operates by virtue of the slow rate that fluid can be transferred through a small aperture from one side of the piston to the other.

D.A.V.C. Abbreviation for delayed automatic volume-control. See DELAYED A.G.C.

db. Abbreviation for DECIBEL.

D.C. Abbreviation for DIRECT CURRENT.

D.C. AMPLIFIER. Amplifying apparatus capable of following the slowest of amplitude changes, sometimes called zero frequency. In practice, such an amplifier might be used to handle slowly changing direct currents, and would be generally similar to the conventional resistance-capacitance type, but with the grid blocking capacitors omitted. Separate power supplies to successive valves then become necessary, as in Fig. 3.

D.C.C. Abbreviation, in reference to conductors, meaning double-cotton covered.

D.C. COMPONENT. That part of a current wave form which is a direct current. Current with certain types of wave form can be simulated by sinusoidal currents to which is added a direct current (see FOURIER ANALYSIS). This direct current is called the D.C. component of a rectified wave. The sinusoids represent the A.C. components. See RECTIFICATION, RIPPLE, SMOOTHING CIRCUIT.

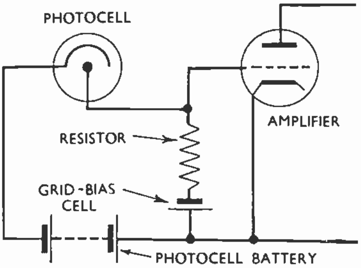


Fig. 2. Simplified circuit which can be used to indicate that dark current is flowing through a photocell.

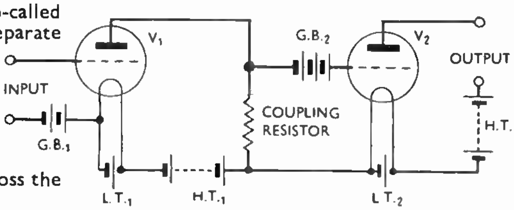


Fig. 3. Simplest form of so-called D.C. amplifier is with separate battery (or mains circuit) to each valve. *G.B.₂* is connected so as to "back off" the otherwise excessive negative bias on the grid of *V₂* from the voltage drop across the coupling resistor.

D.C. GENERATOR. Machine for the production of direct current. It is identical with a D.C. motor; in fact, any D.C. motor may be used as a D.C. generator and any D.C. generator as a motor. For constructional details, see MOTOR.

The series machine is unsuitable for ordinary purposes as, owing to the field windings carrying the armature current, the generated voltage increases as the load is increased. It is often used, however, as a booster to compensate for the drop of volts in a long cable.

The shunt-connected D.C. generator gives a voltage characteristic which falls somewhat as the load is increased, but, so long as the load changes gradually and the generator is under constant supervision, the drop in voltage can be compensated for by adjustment of the field rheostat. When the load is fluctuating, some automatic method of maintaining the voltage is required and the compound machine is used. It is so arranged that the effect of the series winding at full load is just sufficient to compensate for the fall of voltage that would occur if the shunt winding was used alone.

If the load is situated at the end of a long cable, the voltage drop in the cable may be allowed for by "over-compounding" the generator so as to give a higher voltage at full load than at no load.

When compound generators are operated in parallel, it is necessary to connect the series windings of the two machines together on the armature side as well as on the busbar side by means of a low-resistance equalizer bar as shown in Fig. 4. Otherwise a state of instability develops, and one machine takes all the load whilst the other runs as a motor.

D.C. SIGNALLING. Method of communication by line in which the equipment at the receiving end is operated by pulses of direct current sent along the line.

D.C. TRANSMISSION. In electrical engineering, the passage of direct current along lines to operate equipment situated at some distance from the generator (for example, London Transport Underground can be said to employ D.C. transmission); in radio

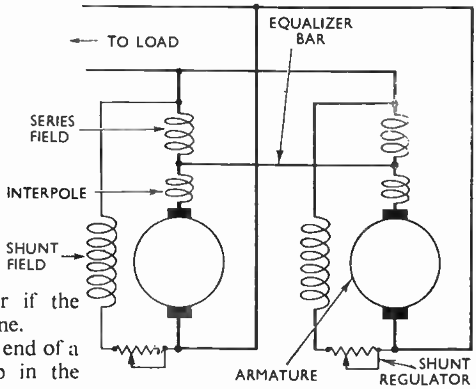


Fig. 4. When compound-wound D.C. generators operate in parallel, it is necessary to connect the series windings together on the armature side by means of an equalizer bar of low resistance.

engineering, the radiation of a modulated carrier wave, the modulation wave form of which includes a D.C. component.

A system covered by the latter definition is used in the B.B.C. television service; the modulation range of 30–100 per cent modulation is arranged to be proportional to the D.C. output of the cameras which, in turn, is a measure of the average brightness of the scene that is being televised.

DEAD-BEAT. Tuned circuit or other potentially oscillatory device (such as the needle of a measuring instrument) so heavily damped that it cannot, in fact, oscillate. If a tuned circuit has what is called critical damping, it will, on being given momentary excitation, make a single unidirectional swing and come to rest. It will not "ring."

A dead-beat measuring instrument displays an immediate steady reading, without swinging or oscillation of its pointer. See DAMPING, RINGING.

DEAD END. Portion of a tapped inductor which is not in use at a given moment. A tapped inductor has one or more intermediate connexions to points on the winding.

DEAD-END EFFECT. Absorption of energy by unused portions of a tapped inductor. It is most marked when the inductance and self-capacitance of the unused portion chance to resonate at the frequency, or a harmonic thereof, to which the rest is tuned.

DEAD-END SWITCH. Device for minimizing dead-end effects by short-circuiting unused portions of a tapped inductor, either as a whole or (more effectively) in sections. It commonly takes the form of a rotary stud switch with a broad wiper blade instead of a narrow finger, as illustrated in Fig. 5. Instead of picking out single studs, the broad wiper or vane covers and connects together all the studs at the unused end of the inductor.

DEBUNCHING. Tendency, in a narrow electron beam, for the particles to spread out because of the mutual repulsion due to their negative charges. This tendency can be counteracted by suitably charged electrodes surrounding the beam, or, as in a gas-focused cathode-ray tube, by having some gas molecules in the tube. The positive ions from these molecules remain relatively static because of their relatively great mass, and those in the path of the electron beam attract the electrons and cause the beam to converge. By this method it is possible to focus the electron beam on the screen. See GAS FOCUSING.

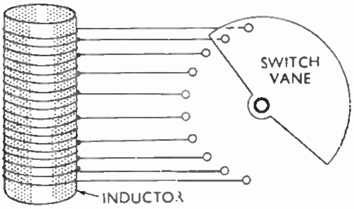


Fig. 5. Rotary type of dead-end switch; as the vane is rotated it connects up the contact studs, so short-circuiting the unused part of the winding.

DECADE INSTRUMENT. Instrument providing values of inductance, capacitance or resistance varying in multiples of ten, for example, 1 ohm, 10 ohms, 100 ohms; 1 henry, 0·1 henry, 0·001 henry. Such instruments are usually designed for precision work in laboratories and have calibrated controls.

DECAMETRIC WAVE. Radio-wave of 10–100 metres wavelength, that is to say, within a frequency range of 3–30 Mc/s. See HIGH-FREQUENCY WAVE.

DECAY COEFFICIENT. Synonym for DAMPING COEFFICIENT.

DECAY FACTOR. Synonym for DAMPING COEFFICIENT.

DECCA. See NAVIGATIONAL AID.

DECIBEL. Number obtained from the logarithm of the ratio of two values of electrical power. If P_1 and P_2 be two powers, then $10 \log_{10} \frac{P_1}{P_2}$ expresses the power ratio in decibels. (A bel is $\log_{10} \frac{P_1}{P_2}$.) Decibel is commonly abbreviated to db.

In the theory and practice of transmission, the decibel is, perhaps, the most used and most useful quantity, because the comparison of powers, rather than voltages, is so frequently necessary in line transmission.

It is more rewarding to compare powers than currents or voltages because, whether the system of transmission is telephony, telegraphy, facsimile or television, power is necessary to send signals through the line and to reproduce the signal in a form intelligible to the human senses. The line carries the messages, but, in so doing, power is lost. Obviously, before designing the equipments for sending and receiving the messages, the power loss in the line must first be calculated, so that it may be restored by amplifiers.

Transmission lines are usually terminated in a resistance equal to their characteristic impedance, so that the best matching is obtained and the only power lost in transmission is that due to attenuation. Because the rate at which power loss increases with the length of the line is an exponential law, the logarithm of the ratios of different amounts of power at different points along the line, which can also be expressed as the loss in decibels, is the same for the same length of line. This means that we can say of any given uniform line, suitably terminated, that its loss is so many decibels per mile, kilometre, or whatever unit of length is desired. Thus, if a line has a loss of 2·0 db. per mile, a line 10 miles long introduces a loss of 20 db.

To compensate for this loss, an amplifier with a gain of 20 db. is wanted. The above example shows how useful it is to have a logarithmic unit to express gain or loss; using this unit, it is unnecessary to work out power loss by calculations involving exponentials.

We can now go further and see that any power lost in transmitting any

DECIBEL TABLE

Greater than Unity

Power	*Decibel*	*Voltage or Current*	*Decibel Gain*
1	0	1	0
2	3·0*	2	6·0*
3	4·8*	3	9·6*
5	7·0*	5	14·0*
10	10·0	10	20·0
20	13·0*	20	26·0*
30	14·8*	30	29·6*
50	17·0*	50	34·0*
100	20·0	100	40
1,000	30·0	1,000	60
10,000	40·0	10,000	80

Fractions of Decibels

Voltage or Current Ratio	*Decibel*
1·01	0·1
1·02	0·2
1·03	0·3
1·04	0·4
1·06	0·5
1·07	0·6
1·08	0·7
1·10	0·8
1·11	0·9
1·12	1·0

Note. Figures marked * are not quite exact, but their error is usually negligible. Thus 3 db. is equivalent to a power ratio of 1·99, not of 2 as stated.

Less than Unity

Power	*Decibel*	*Voltage or Current*	*Decibel Gain*
1	0	1	0
0·5	3·0*	0·5	6·0*
0·2	7·0*	0·2	14·0*
0·1	10·0	0·1	20·0
0·05	13·0*	0·05	26*
0·02	17·0*	0·02	34*
0·01	20·0	0·01	40
0·001	30·0	0·001	60
0·0001	40·0	0·0001	80

wave through any network can be conveniently expressed in decibels. As a corollary, any power represented by so many decibels requires an amplifier of a certain gain in decibels to restore it. A filter may give a certain loss, even in the pass-band; its attenuation characteristic is conveniently expressed in decibels. If a transformer is inserted in a circuit, it inevitably introduces some loss, and this is expressed as an insertion loss in decibels (see INSERTION LOSS).

The power in an electrical circuit is given by the ratio of the square of a voltage acting across the circuit to the resistance of the circuit (see POWER, POWER FACTOR). Thus, if at some point in a circuit there is a voltage E_1 and a resistance R and at another a voltage E_2 and a resistance R, there are two powers E_1^2/R and E_2^2/R. The ratio of these two powers is $\frac{E_1^2}{E_2^2}$ and is independent of R. This makes it possible to express the power ratio in decibels by taking 10 $\log_{10} \frac{E_1^2}{E_2^2}$, or 20 $\log_{10} \frac{E_1}{E_2}$. Similarly, since power is expressed as RI^2, where I is a current, the power comparison in decibels in terms of two currents flowing in equal-value resistors is 20 $\log_{10} I_1/I_2$.

A summary of the arguments set out in the foregoing is contained in the accompanying table. Note that decibels express gain or loss of power. A loss is sometimes given a minus sign and a gain a plus sign (see ACTUAL LEVEL).

Consider now an amplifier, whose input voltage is 0·1 and whose output voltage is 10. The resistance value of the input terminals is 50,000 ohms and the output load is 1,000 ohms. It is a common error to assume that the amplifier has a gain of 40 db. obtained by the ratio of $\frac{\text{output volts}}{\text{input volts}} = \frac{10}{0{\cdot}1} =$ 100. 20 $\log_{10}$ 100 = 40 db.

In fact, because the input voltage acts across a resistance quite different from that at the output, the power ratio must be calculated to get the true gain. Thus, the input power is

$$\frac{0{\cdot}01}{50{,}000} \text{ watts or } \frac{0{\cdot}01}{50} \text{ mW,}$$

and the output power is $\frac{100}{1{,}000} =$ 100 mW; so the gain in power is $\frac{50 \times 100}{0{\cdot}01} = 50 \times 10{,}000 = 50 \times 10^4$, or 40 db. (given by 10^4) + 17 (given by 50), or 57 db.

There is, in fact, a unit which compares the ratio of currents, regardless of the resistance value of circuits. This is called the NEPER (q.v.).

The vital point is that a decibel is a power ratio, and cannot be worked out in terms of voltage or current ratios unless the resistance value of the two circuits is the same. Thus, if a line terminated in its characteristic impedance shows an input voltage of 1 V and an output voltage of 0·1 V, we could compare these voltages to find a loss of 10:1 in volts, representing a loss of 20 db. Similarly, attenuation between the input and output of a symmetrical T- or π-filter can be evaluated simply from a comparison of the voltages at these points.

Attenuators calibrated in decibels are often used in transmission measurements. These are resistance networks (often of 600 ohms characteristic impedance) and switches are used to include, or take out, different sections of the network.

The radio engineer is perhaps not quite so likely to use the decibel, because he is so frequently concerned with voltage amplification and voltage frequency response; if not related to resistive impedance, the decibel becomes meaningless. Moreover, the attenuation of waves when transmitted over distances along the earth's surface does not, as in line transmission, follow an exponential law, and again it is more common and more useful to consider field strengths in absolute, or perhaps in relative, terms. Nevertheless, in the design of networks, equalizers, filters and power amplifiers.

the decibel is of paramount importance and convenience. See ATTENUATION, BEL, INSERTION LOSS, NEPER, POWER, POWER FACTOR.

DECIBELMETER. A.C. voltmeter calibrated in decibels, zero voltage on the meter normally being equivalent to 0·775 volt. This voltage gives a power dissipation of one milliwatt across a resistance of 600 ohms.

DECIMETRIC WAVE. Radio-wave of 10–100 cm. wavelength, that is, within a frequency range of 300–3,000 Mc/s. The propagation characteristics of this type of wave are similar to those of centimetric waves. See CENTIMETRIC WAVE.

DECINEPER. One tenth of a neper. See NEPER.

DECOHERER. Mechanism for ensuring that a coherer ceases to conduct when no longer actuated by the applied signal. An electromechanical device is generally used to apply a gentle vibration to the coherer tube.

DECOUPLER. Network inserted between two circuits with the object of reducing the coupling between the circuits caused by physical connexions such as H.T. and G.B. leads. The term is not used to describe shielding which tends to prevent coupling due to stray electrostatic or magnetic fields. See PADDING.

DECOUPLING. Use of a decoupler circuit or network.

DECREMENT. Rate of dying-away of current in an oscillatory circuit when ringing. More precisely, it is the ratio between the peak value of one oscillation and the peak value of the preceding one, as indicated in Fig. 6. In its usual (logarithmic) form, decrement is given by the expression $\pi R\sqrt{C/L}$, where R is the circuit resistance, L and C being the inductance and capacitance.

DECREMETER. Instrument for measuring decrement by an indirect method involving known changes of reactance in a circuit. The method employs a capacitor with plates so shaped that a given change of dial reading produces a constant percentage change of capacitance in the circuit. See DECREMENT.

DE-EMPHASIS. Reduction in the relative amplitude of the higher modulation frequencies, effected at the receiver, to compensate for pre-emphasis at the sender. See PRE-EMPHASIS.

DEFINITION. In general, the capability of a television system to reproduce detail in the original scene. It is specified numerically by the number of lines of scanning. See HIGH-DEFINITION TELEVISION, LOW-DEFINITION TELEVISION.

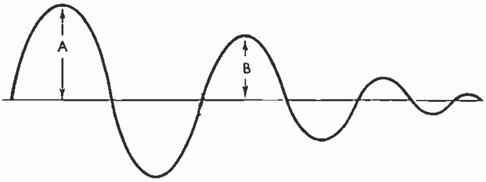


Fig. 6. Damping of an oscillatory current is governed by the decrement of the circuit; the ratio of *B* to *A* (as shown here) is a measure of the decrement.

DEFLECTION DEFOCUSING. In a cathode-ray tube, defocusing which becomes progressively greater as the deflection is increased. Asymmetrical deflection is particularly likely to cause it, because of the effect of unbalanced deflecting potential on the electron lens, and symmetrical deflection is thus preferable. Magnetically deflected tubes are also liable to deflection defocusing unless the deflector coils are very carefully designed to obviate axial components of the field. See ASYMMETRICAL DEFLECTION, ELECTRON LENS, FOCUSING, SYMMETRICAL DEFLECTION.

DEFLECTION SENSITIVITY. Degree of spot displacement, in a cathode-ray tube, resulting from the application of a potential difference of one volt between a pair of deflector plates or a current of one ampere in the deflector coils. Deflection sensitivity equals $\frac{X}{V}$ mm. per deflection volt, where X is a factor characteristic of the tube geometry and V is the voltage of the final accelerator. See CATHODE-RAY TUBE.

DEFLECTION VALVE. Valve used in the cathode-ray tube time base to provide a source of potential or current, the rise and fall of which takes the form of a saw-tooth. This valve may be a thyratron, or a number of valves may be used to form a multivibrator or other form of oscillator circuit. (See TIME BASE).

A cathode-ray tube is sometimes employed for the production of varying currents by deflection of the beam from different "targets" on the screen, and thus might be called a deflection valve. The scheme is used in phase modulators. See ORBITAL-BEAM VALVE.

DEFLECTOR COILS. Coils associated with a cathode-ray tube and used for deflecting the electron beam over the surface of the screen by virtue of the magnetic field produced by the current flowing through them. Those coils which produce horizontal deflection are usually designated X, and those which produce vertical deflection Y. See MAGNETIC DEFLECTION.

DEFLECTOR PLATES. Electrodes in a cathode-ray tube which deflect the beam over the surface of the screen by virtue of the potentials existing between them. Those electrodes which produce horizontal deflection are normally designated X, and those which produce vertical deflection Y. See ELECTROSTATIC DEFLECTION.

DEGASSING. Removal of gas from inside the bulb of a valve. Ideally, the hard-vacuum valve should contain no gas at all; but in practice it is impossible to get a perfect vacuum. Nevertheless, the amount of residual gas left after degassing is very small indeed. The pumps used for degassing are elaborate; usually a motor-driven, oil-immersed pump is used. To get rid of occluded gas, which persists in the pores of the metal constituting the electrodes, these are raised to a high temperature while pumping goes on. The heating is produced by eddy currents induced in the metal by radio-frequency currents passed through coils surrounding the valve. See GAS-FILLED VALVE, GETTER, HARD-VACUUM VALVE, KEEPER.

DEGENERATION. Synonym for NEGATIVE FEEDBACK.

DEGENERATIVE AMPLIFIER. Synonym for NEGATIVE-FEEDBACK AMPLIFIER.

DE-IONIZATION TIME. Time taken for the ions and electrons in an ionized gas to recombine. To ionize a gas, the voltage acting across it must exceed a certain value (see IONIZATION POTENTIAL). For some time after the voltage is switched off, the gas is still conductive; this means that the current flowing in the gas cannot be intermittent if the voltage is switched on and off again sufficiently rapidly. Thus a gas-filled valve will not give intermittent currents following alternating potentials if the frequency is much greater than 50 kc/s, as the gas becomes non-conductive only after a lapse of time sufficient to allow the ions and electrons to combine and become neutral molecules and atoms. See GAS-FILLED VALVE, GLOW-TUBE.

DELAY DISTORTION. Distortion due to variation of the propagation time of the system with frequency. Numerically it is the difference in milliseconds between the time of propagation of the envelope of a wave at any frequency and that of a wave at a specified frequency, usually 800 c/s in telephony. Delay distortion takes place in telephone lines, cables, waveguides (especially near the critical frequency) and, due to ionospheric effects, in electromagnetic propagation. See GROUP DELAY, GROUP VELOCITY, TRANSIENT DISTORTION.

DELAYED A.G.C. Automatic gain-control which does not come into action unless the incoming signal exceeds a certain predetermined amplitude. This is accomplished by the method explained in Fig. 7. Weak signals are thus subjected to the full gain of the R.F. or I.F. amplifier, and strong ones to lower gain so that output remains substantially constant. See AUTOMATIC GAIN-CONTROL.

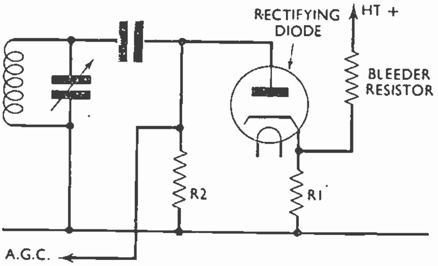


Fig. 7. To prevent A.G.C. from coming into action until the signal exceeds a certain minimum strength, a small negative bias may be applied to the anode of the rectifying diode. In this circuit the bias is obtained from the voltage drop across R_1, which is fed from the bleeder resistor; the A.G.C. voltage is developed across R_2.

DELAYED AUTOMATIC GAIN-CONTROL. See DELAYED A.G.C.

DELAYED AUTOMATIC VOLUME-CONTROL. See DELAYED A.G.C.

DELAYED A.V.C. Synonym for DELAYED A.G.C.

DELAY EQUALIZER. Equalizer which corrects delay distortion. See DELAY DISTORTION.

DELAY NETWORK. Electrical network designed to provide a specified delay in the transmission of currents with frequencies lying within a certain band. Such networks are used in telephone systems to allow time for switches or relays to be operated by speech currents. See DELAY DISTORTION, DELAY EQUALIZER.

DELLINGER FADE-OUT. Complete fade-out of short-wave radio signals. This phenomenon is the result of a burst of ionizing radiation from an eruption on the surface of the sun. It causes an abnormal increase in the ionization of that portion of the ionosphere below the E-layer. Radio-waves travelling through this region are almost completely absorbed.

The effect is usually complete within a few minutes of the eruption and may last for several hours. All parts of the earth illuminated by the sun suffer, but the effect is not apparent at night. The lower the frequency in use, the longer is the duration of the fade-out. See ABSORPTION, FADING, IONOSPHERIC RAY, MAGNETIC STORM.

DEMODULATION. Process which extracts the modulating wave from an amplitude-modulated wave by use of a local oscillator. Although detection and demodulation produce the same result, the processes are different. In demodulation of a modulated wave containing carrier and two sidebands, the modulated wave is remodulated by a wave having the same phase and frequency as the carrier wave.

Sideband frequencies in an amplitude-modulated wave are obtained by adding and subtracting the frequency of the modulating wave, to or from that of the carrier wave (see AMPLITUDE MODULATION, SIDEBAND). Thus a modulated wave contains waves having frequencies of $f_c + f_m$ and $f_c - f_m$, where f_m is the frequency of one sinusoidal modulating wave. If this wave is remodulated by a wave of frequency f_c, then differences of $f_c + f_m - f_c = f_m$ and $f_c - (f_c - f_m) = f_m$ are obtained. The addition of the waves produces waves of frequency $2f_c \pm f_m$. These spurious waves are eliminated by filters. Thus the remodulating of the modulated wave extracts the modulating wave. This remodulating is called demodulation.

The demodulating wave, supplied from a local oscillator, must be synchronized with the carrier wave in the modulated wave: thus it must have the same frequency and the same phase, otherwise the extracted modulating wave is distorted. In the demodulation of a single-sideband modulated wave, it is not necessary to set up synchronism with the carrier wave; but the frequency of the demodulating wave must be very close to that of the carrier wave. See DEMODULATOR, SINGLE-SIDEBAND MODULATION, SUPPRESSED-CARRIER MODULATION.

DEMODULATOR. Device using an oscillator which extracts the carrier wave from a modulated wave. It is essential, first, that the oscillator synchronizes with the carrier wave and, secondly, that the filter eliminates waves of twice the frequency of the carrier wave. Note that no detector is necessary. The difficulty lies in synchronizing the local oscillator without producing beat frequencies in the loudspeaker when tuning-in. Demodulators are chiefly used for the reception of commercial speech transmission in which the modulated wave contains only a single sideband. Precise synchronization is not then necessary. See DEMODULATION, DETECTOR, MODULATION.

DE-POLARIZATION. Action which takes place in a primary cell and tends to reduce the effects of polarization. See POLARIZATION.

DE-POLARIZER. Any chemical producing de-polarization.

DEPTH OF MODULATION. See MODULATION DEPTH.

DEPTH OF PENETRATION. Extent to which a current spreads into the substance of a conductor. Alternating currents of high frequency tend to flow on the surface of conductors, penetrating only to shallow depths; a direct current, on the contrary, distributes itself uniformly through the whole cross-section of the conductor (Fig. 8).

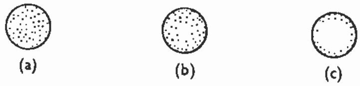

(a) (b) (c)

Fig. 8. Direct current spreads uniformly through the substance of a conductor (*a*). The depth of penetration is less for alternating currents (*b*), and, if of sufficiently high frequency, they are confined to the surface layer (*c*).

DEPTH-SOUNDING. Determining the depth of water beneath a ship. A modern method utilizes beamed trains of supersonic waves sent out by a projector fitted on the bottom of the hull. These waves travel down through the water, are reflected by the sea bed and return to the ship. The velocity of the waves being known, the time that elapses between the transmission of a train of waves and the reception of the echo from the sea bed is a measure of the depth of water.

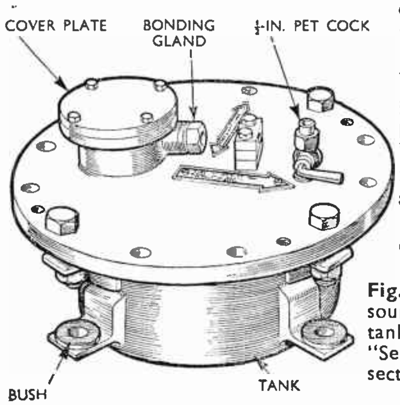
Direct indication of the depth of water is provided by an indicator with a linear time scale. Suppose there are 5 fathoms of sea water beneath the ship. The average velocity of the supersonic waves in sea water being 820 fathoms per second, a total time of 12·2 milliseconds is taken for the waves to travel the total distance of 10 fathoms from ship to sea bed and back to the ship. The indicator is so arranged that at the moment of transmission it reads 0 fathoms and, 12·2 milliseconds later, 5 fathoms.

The principal parts of a depth-sounding installation are:

(1) A transmitter which takes electrical energy from the mains or a battery, transforms it and excites the transmitting projector at appropriate intervals.
(2) A transmitting projector which converts the electrical energy into supersonic waves in the water. In some installations the same projector is used for the reception of the echo.
(3) A receiving projector, if a single projector does not perform the dual function of transmission and reception, to convert the supersonic waves of the echo into electrical energy.
(4) An amplifier to amplify the echo

signal sufficiently to operate the indicating apparatus. In some installations, the transmitter and amplifier circuits are contained in a single transmitter-receiver unit.

(5) A recorder and/or visual indicator, together with a timing device to trigger the transmitter when the scale indication is at zero.

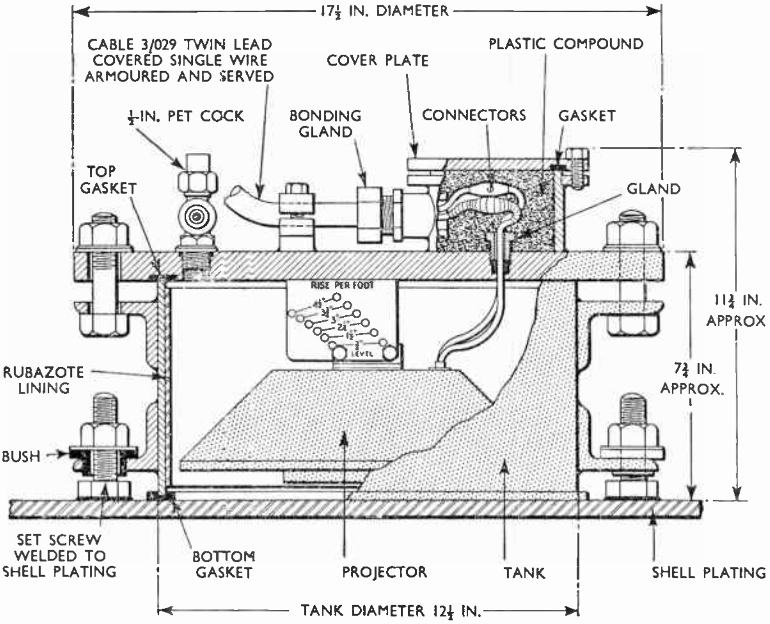


Of the projectors used in marine installations, there are two main types, operating on magneto-striction and piezo-electric principles respectively.

In the Marconi equipment known as the "Seagraph" Echo-sounder, the projector is of the high-power magneto-striction type. It may be installed either in a hull casting, and thus in direct contact with the sea, or internally so that transmission and reception take place through the ship's shell plating. The former method, known as the pierced-hull method, gives an improved performance in deep water or under bad weather conditions when the echo may be considerably weakened by aeration below the ship.

With pierced-hull installation, only one projector is required, acting as

Fig. 9. An example of modern depth-sounding equipment; (*left*) the projector tank of the internally installed Marconi "Seagraph" Echo-sounder, and (*below*) a section of the assembly, showing the projector in the tank.



both transmitting and receiving projector, but two are normally installed, one acting as a stand-by. With internal fitting, two projectors must be used, one for sending and the other for reception.

The projector consists of a flat circular magneto-strictive element built up in the form of a deep annular ring which has a natural frequency of vibration of 14 kc/s, approximately. A conical reflector is used to redirect the vibrations from the circumference of the element from a horizontal to a vertical direction.

When the projector is fitted internally, the element is mounted inside a tank, secured to the bottom plate of the ship (Fig. 9), and filled with fresh water. When the ship's hull is pierced, the projector is secured inside a steel casting which surrounds the inner side of a hole in the shell. The upper end of the casting is sealed off with a heavy steel plate and the projector is sealed from the sea by a thin stainless steel cover, filled with fresh water, and so arranged that it fills completely the cavity made in the shell plating.

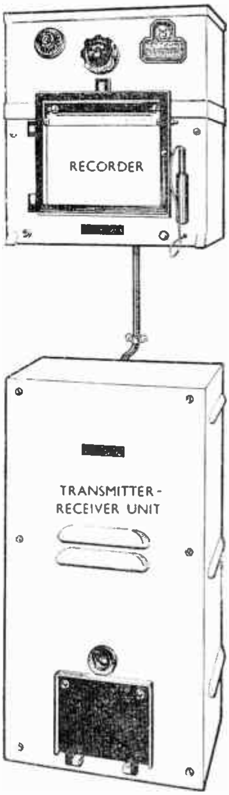


Fig. 10. Above the "Transceiver" unit of the Marconi "Seagraph" Echo-sounder is a depth recorder unit which provides a graph of the kind shown in Fig. 12.

The transmitter and the amplifier circuits are contained in a single "Transceiver" unit (Fig. 10). This unit also contains a power-supply unit for the whole equipment. The power-supply unit is suitable for operation either from a 24-volt battery or from the ship's D.C. mains (110 volts or 220 volts). H.T. voltages are obtained by means of a vibrator and a system of transformers and rectifiers.

The transmitter (Fig. 11) consists of a 2-μF capacitor and a mercury-vapour discharge tube, connected in series with each other and with the projector winding. Its action is as follows: The capacitor is charged up to 1,200 volts through a high resistance from the power-supply unit. This voltage is also impressed on the anode of the mercury vapour tube, but the latter cannot operate until it is "struck" by a considerably higher voltage.

The keying switch in the recorder is connected in series with the primary of a high-ratio step-up transformer. When

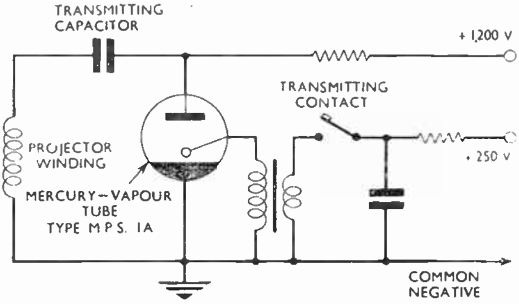


Fig. 11. Basic transmitting circuit of the "Seagraph" depth-sounding equipment described in the text.

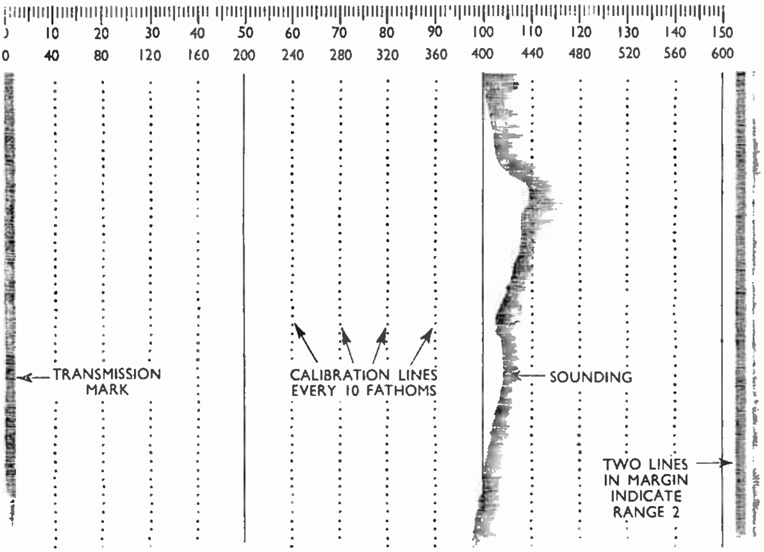


Fig. 12. Portion of a typical depth-sounding record produced by the Marconi "Seagraph" equipment operating, in this case, on range 2 (0-150 fathoms). The marks made by the stylus form a contour of the sea bed.

the switch closes, a high-voltage pulse, of the order of 12,000 volts, is produced in the secondary of this transformer and applied to the ignition electrode of the mercury-vapour tube.

The tube is triggered off and the transmitting capacitor discharges through the projector winding. The mercury-vapour tube extinguishes at the end of the first half-cycle. The sudden release of the energy in the capacitor into the transmitting projector shock excites the latter, causing the magneto-strictive element to vibrate at its own natural frequency.

The amplifier contains four valves, resistance-capacitance coupled. The input is tuned to 14 kc/s. The output circuit of the final stage is tuned and connected to a full-wave rectifier system, the output of which is taken to the recorder stylus.

During transmission, the input of the amplifier is short-circuited. This is achieved by the use of an auxiliary anode in the mercury-vapour discharge tube. Use is made of an automatic time-controlled gain system that depresses the gain considerably at the recorder-scale zero and progressively less as the indicator advances over the scale, the condition for maximum gain being reached at the 200 fathoms mark, approximately.

The recorder (Fig. 10) provides a paper record of the depths of water beneath the ship. A typical sounding record is shown in Fig. 12. The recorder stylus, which runs in a straight line across sensitized paper, is attached to an endless belt and is driven at a uniform speed, corresponding to the range scale in use.

The paper is used in a damp condition and when an echo pulse of current from the amplifier passes from the stylus through the paper, iodine is liberated and leaves a brown mark. The paper is pulled slowly past the moving stylus and, since there are many transmissions per minute, the marks join together into a continuous line that forms a contour of the sea bed.

The contact that closes the trigger circuit of the transmitter when the stylus is at the scale zero is operated by a keying button on the stylus belt.

Graduation lines are electrolytically printed on the record, showing 10-ft., 10-fathom or 40-fathom intervals, depending upon the range in use. An indication of the range is also automatically printed on the record in the form of vertical lines at the right-hand side: one line for Range 1, two lines for Range 2 and three lines for Range 3.

The three ranges are:

Range 1, 0–150 ft. (0–25 fathoms);
Range 2, 0–150 fathoms;
Range 3, 0–600 fathoms.

The rates of sounding are:

Range 1, 209 soundings per minute;
Range 2, 48·5 soundings per minute;
Range 3, 12·0 soundings per minute.

DERIVED UNITS. Any system of units derived directly from the basic units of length, time and mass. See PRACTICAL SYSTEM OF UNITS.

DETECTION. Process of making audible (or otherwise reproducible) the variations of amplitude (or frequency) of a modulated carrier wave. The frequencies of the currents used in the generation of wireless waves are well above the limits of audibility and consequently the currents picked up on a receiving aerial cannot be heard directly.

It is necessary to modulate the currents in the transmitting aerial in some way, the most common method being to vary the strength, or amplitude, in accordance with the intelligence to be conveyed (see MODULATION). Similar variations in amplitude then occur in the received signal, but, as these variations are still only changes in the strength of a carrier wave which is oscillating many hundreds of thousands of times per second, the mean value is still zero. It is necessary, therefore, to introduce some device which will respond to the modulation, that is to say, one that will provide a current proportional to the changes in amplitude, which is what we are primarily interested in.

The most usual way of doing this is to introduce into the circuit some device which conducts current more easily in one direction than in the other. The mean value of the current is then no longer zero, but varies in accordance with the changes in strength of the carrier. This will be clear from Fig. 13, where the first line shows a modulated carrier, that is to say, a high-frequency oscillation of which the strength is varying at a lower frequency. For simplicity, the

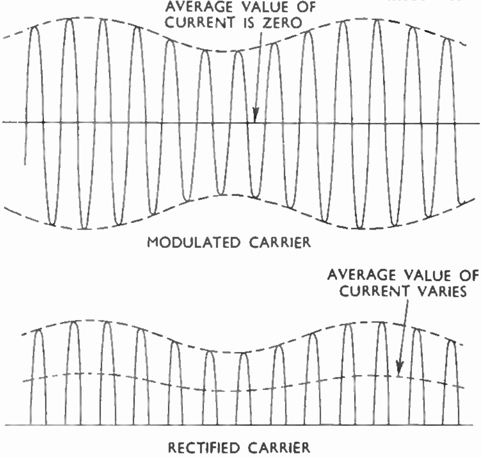


Fig. 13. Effect of detection on a high-frequency oscillation; the average value of current is zero in the modulated carrier, but varies in accordance with the modulation when the carrier-wave is rectified.

carrier frequency has been chosen at only about ten times the modulation frequency so that the individual waves can be shown clearly; but in practice, the carrier frequency is many hundreds, or even thousands, of times greater than the modulation frequency.

The second line shows the effect of passing this current through a non-linear device which cuts off the current completely in one direction. It will be seen that the mean value of the current is now changing with the modulation. If such a current were passed through a telephone receiver, for example, the receiver, while unable to take any account of the high-frequency carrier current pulses, would respond to the variations in mean current.

An ideal detector would pass no current at all in one direction, but permit current in the forward direction to an extent which was strictly proportional to the voltage applied across the circuit. Such detectors, however, are not found in practice. Crystal rectifiers (see CARBORUNDUM DETECTOR and CRYSTAL DETECTOR) pass an appreciable reverse current, though this is considerably less than the forward current, and does not seriously affect the performance. In the case of a diode rectifier, the reverse current is so small as to be negligible.

A more serious source of difficulty is that the changeover from the non-conducting to the conducting condition is not sudden but gradual, so that the "knee" of the curve is not sharp. It will be clear, therefore, that the current which will flow is not directly proportional to the applied voltage, being smaller with small voltages than with large.

Most detector characteristics are fairly linear beyond the knee. In other words, beyond the transition portion, the characteristic is approximately a straight line, so that the current output is proportional to the voltage applied. For this reason, arrangements are made, in all except the simplest receivers, to amplify the radio-frequency signals before applying them to the detector, so that the signals are of such a strength as to swing well beyond the initial curved portion of the characteristic. See DETECTOR, LINEAR DETECTION.

DETECTION COEFFICIENT. Ratio of the actual audio-frequency output from a detector to the theoretical output obtainable with perfect rectification. In a practical detector circuit, we apply the signal to a detector in series with a load. This may be a pair of telephones in a simple crystal receiver, but is more usually a resistance-capacitance combination (see DIODE DETECTOR).

The audio-frequency voltage is developed across the total circuit impedance consisting of the load and the detector in series. Hence only part of the total audio-frequency voltage is actually available across the load. Thus, if we had a carrier input of 1 volt modulated to a depth of 30 per cent, we should expect 0·3 volt audio-frequency output; whereas, in practice, we should obtain only about 0·25 volt, corresponding to a detector efficiency of 83 per cent.

To maintain a high efficiency, the load impedance should be made large compared with the internal resistance of the detector. With practical circuits, this requires a load of 0·1 to 0·5 megohm.

The internal resistance of a practical detector decreases appreciably as the signal strength increases. Hence the detection coefficient improves with increasing signal strength. With very weak signals it is likely to fall well below the figure quoted above, which is a further reason for the use of radio-frequency amplification prior to the detector stage.

DETECTOR. Device with a non-linear current/voltage characteristic used to separate the modulating wave from a modulated carrier wave. The term is generally used in connection with amplitude modulation; a detector for frequency-modulated or phase-modulated waves is usually known as a DISCRIMINATOR (q.v.).

Though some types of detector circuit are very similar to rectifier circuits, the essential difference between them is that, in general, the input to a detector is a modulated wave and its output is at modulating-wave frequency, whereas the input to a rectifier is an unmodulated wave and its output is D.C.

The simplest type of detector consists of a contact between two dissimilar conductors or semi-conductors which are chosen to have the essential property of conducting more readily in one direction than in the other. Possibly the first type of detector to be used was a copper wire in contact with a crystal of galena; more modern counterparts of this are the copper-oxide detector and the germanium or silicon crystals extensively used for detecting centimetric waves during the Second World War.

The majority of detectors are, however, electronic valves: the most popular type is probably the diode detector, which is used almost universally in modern radio receivers. Other types of valve detector include the leaky-grid, the anode-bend and the infinite-impedance detectors.

In the early days of the superheterodyne receiver, the frequency-changer was known as the *first* detector, while the real detector was called the *second* detector. The frequency-changer has the function of transferring the modulation from a carrier wave of one frequency to a carrier wave of a different, and usually lower, frequency; but this does not agree with the definition of a detector and the term "first detector" was thus a misnomer. Nevertheless, there was some justification for use of the term because the early frequency-changers did embody some form of detector, usually of the anode-bend type. Frequency-changing was achieved in those days by adding (connecting in series) the output of the local oscillator with the output of the R.F. amplifier. The result of such an addition is a complex wave from which the wanted output at the difference frequency can be obtained only by the process of detection. Thus the additive type of frequency-changer necessarily embodies some form of detector.

Modern frequency-changers operate on an entirely different principle: the output of the oscillator and that of the R.F. amplifier are, in effect, multiplied together and the wanted output at the difference frequency is obtained directly and without the necessity for any form of detector. Multiplicative frequency-changers cannot, therefore, be classed as detectors, nor do they contain detectors. See ANODE-BEND DETECTION, GRID DETECTION, INFINITE-IMPEDANCE DETECTION.

DETUNING. Act or process of adjusting the tuning of a circuit or apparatus away from a particular frequency. It is sometimes done, for example, in the intermediate-frequency circuits of a superheterodyne receiver, in a particular manner to obtain some desired shape of resonance curve.

DEVIATION RATIO. Ratio of the frequency deviation of a frequency-modulated wave to the maximum frequency of the modulating wave. See FREQUENCY MODULATION.

DIAGONALIZING. System of allocation of carrier-wave frequencies to broadcasting senders in a continental area in which senders geographically close together use carrier-wave frequencies which are widely different. Diagonalizing is intended to minimize interference between broadcasting senders caused by the overlapping of sidebands in the service areas of senders which are close to one another. There is little virtue in the system because, at night, the reflected ray from even far-distant senders is strong enough to cause interference in a B-service area. See IONOSPHERE, SERVICE AREA.

DIAGRAM SYMBOLS. See SYMBOLS.

DIAL. Plate, usually circular and bearing radial graduations, which is used in conjunction with a pointer to indicate units of measurement in a variable component. The dial may be fixed and the pointer rotated over it, or the pointer or index mark may be fixed and the dial rotated past it. In a broadcast receiver, the wavelength or frequency dial may be marked also with the names of broadcasting stations at appropriate points on the scale.

The term has a special meaning in telephony; it is used to describe the rotatable plate with finger holes with which a subscriber sends trains of impulses to an automatic telephone exchange when making a call.

DIAMAGNETIC. Property of having a lower magnetic permeability than unity; lower, that is, than the permeability of a vacuum.

DIAMOND AERIAL. Aerial designed to cover a considerable band of frequencies, consisting of a half-wave dipole in which each half resembles a CONICAL AERIAL (q.v.); the broad ends of the two cones are placed adjacent to each other, however.

DIAPHRAGM. Thin plate or cone supported at its periphery. When subjected to air pressures produced by sound waves, the diaphragm vibrates at the frequency of the sound. The vibrations thus produced may be converted into electrical energy, as in the microphone. Conversely, if an iron diaphragm is placed in the field of an electromagnet, it can be made to vibrate at audio frequency by applying speech currents to the electromagnet; this principle is applied to the loudspeaker and the headphone. See HEADPHONE, LOUDSPEAKER, MICROPHONE.

DIELECTRIC. Insulating material, especially that separating the plates of a capacitor.

DIELECTRIC CONSTANT. Synonym for RELATIVE PERMITTIVITY.

DIELECTRIC HYSTERESIS. Time-lag effect shown by a dielectric material in recovering from subjection to an electric strain.

DIELECTRIC LOSS. Energy dissipation in the dielectric of a capacitor when carrying an alternating current. The theoretically perfect capacitor has zero loss, but, in practice, energy loss is caused in various ways; for instance, by the imperfections of the insulating material between the plates; when carrying a heavy current the dielectric heats up—a sure sign of energy loss. Dielectric losses can, of course, occur wherever there is capacitance between parts of a circuit at different potentials. The extent of the loss depends on the "quality" of the dielectric material. See CAPACITANCE.

DIELECTRIC STRENGTH. Synonym for ELECTRIC STRENGTH.

DIELECTRIC STRESS. Synonym for ELECTRIC STRENGTH.

DIFFERENTIAL ANODE CONDUCTANCE. Synonym for ANODE SLOPE-CONDUCTANCE.

DIFFERENTIAL ANODE IMPEDANCE. See ANODE IMPEDANCE.

DIFFERENTIAL ANODE RESISTANCE. Synonym for ANODE SLOPE-RESISTANCE.

DIFFERENTIAL ELECTRODE CONDUCTANCE. Synonym for ELECTRODE SLOPE-CONDUCTANCE.

DIFFERENTIAL ELECTRODE IMPEDANCE. See ELECTRODE IMPEDANCE.

DIFFERENTIAL ELECTRODE RESISTANCE. Synonym for ELECTRODE SLOPE-RESISTANCE.

DIFFRACTION. Effect occurring in the lower air-layers above the earth which enables the ground wave of a sending station to follow the curvature of the earth and travel beyond the optical range. When a wave is travelling over an imperfectly conducting body, such as the earth, the electric field of the wave must have a component horizontal to the earth, because the currents induced in the earth require potential differences over the surface to produce them.

The electric field of a vertically polarized wave is, therefore, no longer vertical, but tilted, the foot dragging behind. The exact angle of tilt depends upon the conductivity and the relative permittivity of the area over which the

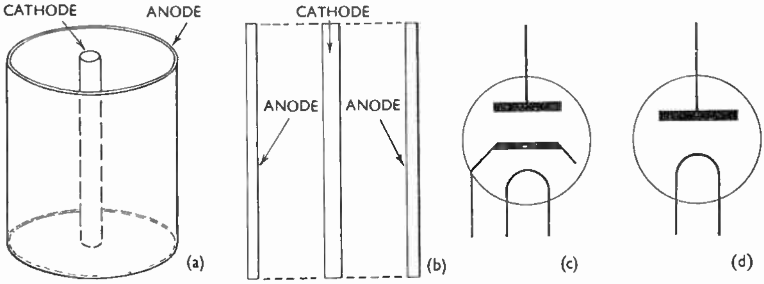


Fig. 14. Basic features of the diode (*a*); vertical section of electrodes (*b*); representation of the diode with (*c*) an indirectly heated and (*d*) a filament cathode.

wave is travelling. The effect of diffraction is well known in connexion with light rays, where the rays "leak" around an opaque body and illuminate an area which one would expect to be in shadow if the rays followed straight lines.

The effect of diffraction becomes greater as the wavelength increases, and this partly accounts for the fact that the ground wave travels longer distances as the wavelength is increased. As the wavelength is reduced, however, the ground-wave range becomes very small, and, on ultra-short wavelengths, it may not be much more than the optical range. See ABSORPTION, CONDUCTIVITY, PERMITTIVITY, POLARIZATION.

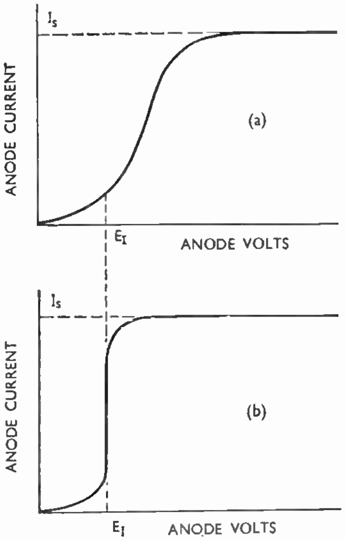


Fig. 15. Anode-volts/anode-current characteristics of (*a*) a hard-vacuum diode and (*b*) a gas-filled diode. Below the ionization potential E_I both graphs are the same, and the maximum current I_s is the same in each.

DIODE. Valve having two electrodes, namely, anode and cathode. A diode and its diagrammatic representation are shown in Fig. 14. A diode used in a mains unit is known as a rectifier valve; it is known as a detector when used to rectify radio-frequency waves.

The diode may be either a hard-vacuum or gas-filled type. When gas-filled, it is used to rectify mains A.C. The hard-vacuum diode is used for mains rectification and the detection of radio-waves.

The anode-volts/anode-current characteristics of a hard-vacuum and a gas-filled diode are shown in Fig. 15; both valves exhibit the same characteristics at low anode voltages while the current is limited by SPACE CHARGE (q.v.). Once space-charge limitation no longer applies, a hard-vacuum diode exhibits a uniform anode slope-resistance. When the anode current reaches the total emission of the cathode the graph becomes horizontal, as the cathode cannot supply any more electrons to provide the increased current which would flow, in a conductor obeying Ohm's law, with increased voltage.

The state of affairs in a gas-filled diode is different: once the gas is ionized, positive ions attracted to the space charge neutralize it and the current increases, causing more ions to form. Anode current is thus increased until this quantity reaches saturation. See EMISSION LIMITATION, GAS-FILLED DIODE, IONIZATION, MERCURY-ARC RECTIFIER, SPACE CHARGE, SLOPE RESISTANCE.

DIODE DETECTOR. Two-electrode valve used for detection. Detector diodes are made of small dimensions to reduce self-capacitance, and are designed to have a low internal A.C. resistance so that the detection coefficient shall be as high as possible.

The application of one form of diode detector is shown in Fig. 16. The diode is in series with a load resistor and a parallel capacitor. On the arrival of a signal, the diode conducts when its anode is positive. The resulting current charges the capacitor to a voltage nearly equal to the peak value of the applied signal. Some of the charge leaks away through the resistor during the remainder of the cycle. On the next positive peak the diode conducts again when the applied signal exceeds the voltage to which the capacitor has charged, and makes good the loss which has taken place through leakage. The action is illustrated in Fig. 17.

If the signal is varying in amplitude, as in the case of a speech-modulated carrier, then, provided the modulation changes are slow in comparison with the carrier frequency (which is always the case in a practical system), the voltage on the capacitor will adapt itself all the time to the changing amplitude, so that the voltage across it varies in accordance with the modulation voltage.

For this process to be reasonably faithful, the time constant of the resistance-capacitance circuit must not be too long (see TIME CONSTANT). In other words, the value of the resistance relative to the capacitance must be low enough to permit the charge to leak away at least as fast as the most rapid change of carrier amplitude corresponding to the highest modulation frequency.

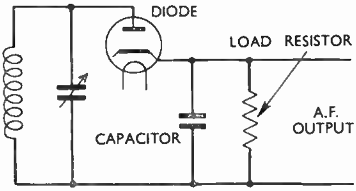


Fig. 16. Circuit showing application of one form of diode detector. Resulting action is illustrated in Fig. 17.

If the capacitance is too large and/or the resistance is too high, the charge cannot leak away sufficiently rapidly, and distortion will result. This shows itself as a loss of upper frequency in the response while, if the time constant is very much too large, the circuit fails to follow the modulation, and the reproduction sounds choked.

A second form of circuit is shown in Fig. 18. Here the resistor is connected

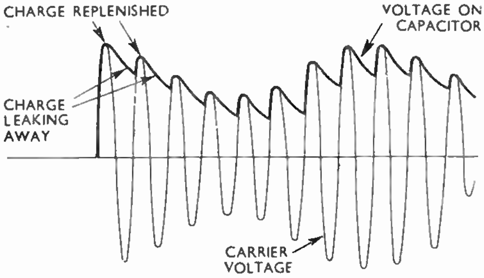
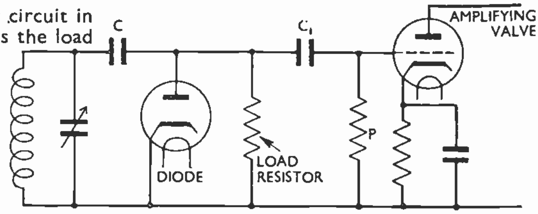


Fig. 17. Diagram showing the wave form produced by the alternate leaking-away and replenishment of the charge on the capacitor in the diode-detector circuit of Fig. 16.

across the diode. The action is the same as for Fig. 16. The capacitor *C* charges on the peaks of the carrier, the charge then leaking away through the resistor during the period that the diode is non-conducting. In the circuit of Fig. 18 the voltage across the load resistor has been transferred to an amplifying valve through a coupling capacitor C_1 and leak. This second network modifies the effective diode load at modulation frequencies. To avoid distortion, the resistance of *P* should be at least four times the diode load resistance.

Fig. 18. Diode-detector circuit in which the voltage across the load resistor is applied to the grid of an amplifying triode. To avoid distortion the value of *P* should be at least four times the load resistance.



DIPLEX OPERATION. In telecommunication, the transmission or reception of two separate messages on a single set of equipment.

DIPLEX RECEPTION. Reception of two transmissions of different frequencies by means of two receivers working on a common aerial.

DIPOLE. Synonym for HALF-WAVE DIPOLE.

DIPOLE AERIAL. See HALF-WAVE DIPOLE.

DIRECT ADMITTANCE. The reciprocal of direct impedance. See DIRECT CIRCUIT, DIRECT IMPEDANCE.

DIRECT BEARING. Direction of a distant point measured along the shorter of the two possible Great Circle directions. See BEARING, RECIPROCAL BEARING.

DIRECT CAPACITANCE. See DIRECT IMPEDANCE.

DIRECT CIRCUIT. In telegraphy, a circuit in which currents are transmitted from one station to operate the distant signalling instrument without the use of relays at intermediate points along the route.

DIRECT COUPLING. Coupling of circuits by physical connexion between them, as distinct from INDUCTIVE COUPLING (q.v.). Direct coupling is otherwise called common-impedance coupling, and the current path may be either capacitive or resistive.

DIRECT CURRENT. Current which flows steadily in one direction, and without regular variations in strength. Direct current (D.C.) is that given by the simplest sources, such as the primary battery or accumulator, and is the simplest form of electrical energy. Its effective value in a circuit, for instance, is fixed merely by the strength of the electromotive force or voltage and by the natural opposition of the circuit (more technically known as its resistance). There are no complications such as arise with alternating currents (A.C.).

The magnitude of D.C. varies directly with the voltage—twice the voltage means twice the current—and inversely with the resistance: twice the resistance means half the current, and so on. Again, the power which it delivers is found simply by multiplying the voltage by the current; a current of 5 amp. at a pressure of 10 volts gives a power of 50 watts. Another form of the same relationship states that, in a circuit of given resistance, the power is proportional to the square of the current. This follows because to double the current it is necessary to double the voltage also, and that is equivalent to multiplying the product of these quantities by four.

Although D.C. is not so universally useful as A.C., it has many special applications. D.C. is valuable, for example, in electric traction; the D.C. motor is more flexible than most A.C. types, and lends itself to fine adjustment of power and speed, as well as being capable of starting under heavy loads.

Various electrolytic processes demand the use of D.C.; electro-plating is possible only with a non-reversing flow of current, and accumulators can be charged only by means of such a current. Arc lights, too, are best run from D.C. and cinema projectors are therefore provided with a direct-current supply.

Direct currents of small power are customarily obtained from primary batteries or from accumulators; the bigger currents needed for electroplating and arc lamps may be obtained from big rectifiers of, for instance, the mercury-arc type, or from the kind of rotating generator called a dynamo. This machine is essentially similar to the alternator, in that it consists of an armature which carries a winding, or series of windings, and is revolved in an intense magnetic field. The dynamo, or D.C. generator, differs from the alternator in having a form of rotating switch fitted to the armature shaft to alter the connexions of the armature windings as they turn so as to keep the current flowing out of the machine always in the same direction.

The principle of the dynamo is simply that of ELECTROMAGNETIC INDUCTION (q.v.), seen also in the transformer, the alternator and many other devices used in electrical engineering and radio communication. The powerful magnetic field, in which the armature is spun, is produced by an electromagnet fed with current generated by the machine itself; the electromagnet windings may be in series with the armature, so that they carry the whole output current of the dynamo, or they may be in parallel, carrying only a fraction of the output. These two types of D.C. generator are known respectively as series and shunt machines.

Direct currents are used in radio for the anode supply of valves, and also for developing the grid-bias voltages. In the common type of mains receiver, D.C. is obtained by rectifying and smoothing an alternating voltage provided by a transformer (see RECTIFICATION, SMOOTHING CIRCUIT). D.C. is little used for general power distribution, mainly because it cannot be transformed up and down in voltage without the use of rotating machinery See ALTERNATING CURRENT.

DIRECT-DISC RECORDING. System of gramophone recording in which the recorded disc may be reproduced without resorting to processing. See ELECTRICAL RECORDING.

DIRECT DRIVE. Sending system in which there is direct coupling between aerial and oscillator circuit.

DIRECT IMPEDANCE. Impedance (or capacitance, inductance, resistance, etc.) existing between two terminals of a network having several terminals. The term is more likely to be used in connexion with the analysis of the theory of transmission, than with day-to-day practice and design.

Direct impedance may be more fully defined as a term indicating that the quantity specified is that pertaining to the current path or paths directly connected to the two terminals specified, any current reaching these terminals by way of any other terminals being left out of account in measuring or reckoning the quantity concerned. See CIRCUIT, NETWORK.

DIRECT INDUCTANCE. See DIRECT IMPEDANCE.

DIRECTIONAL AERIAL. Synonym for DIRECTIVE AERIAL.

DIRECTIONAL RECEIVER. Complete receiver and aerial-system so designed that reception efficiency is at a maximum on signals from a particular direction.

DIRECTIONAL SENDER. Complete sender and aerial-system so designed that radiation is at a maximum in a particular direction. The direction may be fixed as for a station designed to communicate with another of known position, or it may be variable, as in a directive-signalling beacon.

DIRECTION-FINDER. Complete apparatus, including aerials and receiver, for determining the direction of arrival of radio-waves. The simplest direction-finder is a receiver working from a loop-aerial (Fig. 19). The strong directional properties of this combination must be familiar to users of portable receivers, which must be turned to either of two diametrically opposed directions to receive maximum signals from a station (see RECIPROCAL BEARING). Midway between these two settings there is another orientation in which signal strength is nil or is greatly reduced. This minimum position is normally more sharply defined than the maximum and is therefore used in determining bearings with this and most other direction-finders.

In its simplest form, the plain loop direction-finder will not indicate which of the two possible orientations denotes the true direction of the sender; the minimum-signal position merely shows that the loop is broadside on to the wave front but does not indicate from which side the waves are approaching. A comparatively minor modification, however, enables the direction to be determined (see SENSE-FINDING).

The loop direction-finder is subject to errors, which are minimized in more highly developed types; but its simplicity and compactness make it attractive wherever great precision is not essential. In a practical installation, such as on a ship or aircraft, the loop is usually constructed in a convenient weather-proof form and mounted externally; for example, on the roof of the ship's radio cabin or under the fuselage of an aircraft. The loop is then provided with a remote control, usually of a simple mechanical kind, but sometimes employing a pair of self-synchronizing motors, enabling it to be turned by the operator sitting at his receiver.

The loop must be small so that it can be rotated easily; it is therefore a somewhat inefficient pick-up device for medium and low frequencies. This in turn indicates the need for a high-gain receiver, which was not available in the early days of direction-finding work. For permanent ground installations, therefore, other types were developed in which the aerial or aerials need not turn. In the Bellini-Tosi system, for instance, fixed loops are used; these are connected to the field coils of a goniometer, the search coil of which is used to determine the equivalent direction of wave travel (see BELLINI-TOSI DIRECTION-FINDER).

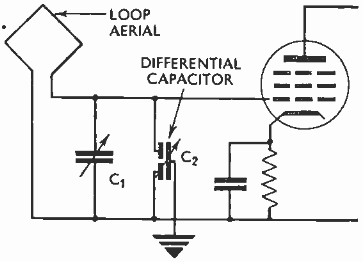


Fig. 19. First stage of a simple loop direction-finder. The rotatable loop is tuned by C_1, while the differential capacitor C_2 equalizes the stray capacitance to earth from the two sides of the circuit to eliminate antenna effect.

As the loops need not rotate, they can be made large and capable of effective pick-up, especially on medium frequencies; and receiver gain need not be high, a strong point in favour of the system when it was first developed. Now that highly sensitive receivers of stable and robust types are available, the loops need not be so large, and Bellini-Tosi direction-finders are often used on shipboard.

In closed-loop direction-finders, certain residual errors are troublesome, and the spaced open-aerial type is consequently often preferred when space permits, as, for instance, on ground stations (see POLARIZATION ERROR, RADIOGONIOMETER, SPACED-AERIAL DIRECTION-FINDER).

In a typical form, there are four open aerials symmetrically spaced and connected in opposite pairs to a goniometer in the receiver building, which is situated at the centre of the aerial-system. Direction-finders of this sort can be arranged to minimize errors produced by such phenomena as the presence in the radiation of components which are polarized in other than vertical directions.

At night it is common for waves which have travelled some distance to contain a substantial proportion of erratically polarized radiation; the simple loop or Bellini-Tosi direction-finder is therefore sometimes incapable of giving correct bearings after dark, whereas the Adcock in its most effective form will continue to do so.

A typical spaced-aerial direction-finder of the Adcock type for operation on medium and long wavelengths consists of four mast aerials, each about 120 ft. high, set at the corners of a square having 200-ft. sides, with the receiver building situated in the centre.

From the base of each mast, a buried and screened concentric feeder runs to the receiver hut, and to the goniometers of the receiver. One goniometer is provided for each frequency range to be covered. Suitable switching arrangements connect the relevant goniometer to the receiver, which is a highly sensitive superheterodyne with separate oscillator for beat reception of unmodulated signals, and possibly a note filter and other refinements for dealing with jamming.

For sense-determination, a fifth, vertical aerial is usually provided which can be combined with the direction-finding aerials to produce an asymmetric polar diagram. This sense aerial is commonly hung immediately above the receiver hut, with its upper end supported by triatic stays running between the tops of the aerial masts. See CARDIOID DIAGRAM, SPACED-AERIAL DIRECTION-FINDER.

DIRECTION-FINDING. Determination of the bearing of a distant sender by means of observations on the signals received from it. The basic principles of direction-finding are of the utmost simplicity, and to the first experimenters it must have seemed to offer a navigator's aid of truly revolutionary importance. To all appearances it is necessary only to set up a sharply directive, rotatable-aerial system such as a loop of suitable design, orientate it by seeking the setting for minimum signal, which is usually more sharply defined than the maximum, and read off the bearing which it indicates. In favourable conditions it may indeed be as simple as that, and the bearing of the distant sender can be decided to an accuracy of two degrees or better.

Given bearings of similar accuracy on two or more distant senders suitably situated, the observer can fix his own position with some precision on a map showing the positions of the two senders; from these he draws lines corresponding to bearings which are the reciprocals of those he has measured with his direction-finder (see RECIPROCAL BEARING). The intersection of the lines indicates the observer's position. Alternatively, the navigator of a ship or aircraft who wishes to fix his position may enlist the help of ground direction-finding stations, asking them to take bearings on him while he sends a test signal.

The ground direction-finders are generally arranged in chains of two or three widely spaced stations connected by land-line telephone. One of the stations, acting as "control," receives telephoned bearings from the other stations in the chain, combines them with its own, plots all bearings on a map and then signals a position or fix to the inquirer. Despite the apparently lengthy procedure involved, this system has been so highly developed that the navigator is given the required information in under a minute.

The latter method has an advantage in that the somewhat elaborate and specially calibrated apparatus needed for accurate direction-finding can be carefully located on a well-chosen permanent site, thus obviating the limitations and error-prone complications of shipboard or aircraft use. On the other hand, the method is relatively cumbersome and is expensive. Ships and aircraft therefore often carry their own direction-finding gear, for use when a quick position check is required, or when out of range of suitable D.F. stations.

Direction-finding is not, in fact, the simple and accurate process that it seems. Study of the behaviour of radio-waves, and of directive aerial-systems, reveals many complications. It is found, for instance, that radio-waves do not necessarily follow shortest-distance-between-two-points paths; often they are deflected, and arrive at the direction-finder from a false direction after reflection from a ground feature or an irregularity in the E-layer or F-layer.

Or the direction-finder may find itself receiving a mixture of direct and reflected ray, which is likely with some equipments to result not only in actual errors but in bearings so indefinite as to be almost useless. The aerials and aerial-circuits themselves are also potential sources of error (see ANTENNA EFFECT, POLARIZATION ERROR).

Indeed, it is remarkable that direction-finder bearings are so accurate. An experienced operator can generally recognize the conditions likely to produce major errors, and can warn his navigator against undue reliance on D.F. position at such times.

As an alternative to the methods just described, direction-finding may be done with the aid of directive transmissions from senders at known positions (see BEACON DIRECTION-FINDER). Such methods are often of only moderate accuracy, but they have the advantage of being simple to use; the user is not required to measure the bearing, but to observe certain indications which show when the sender is directing its radiation straight towards him. At that moment, the signals themselves carry a coding enabling the observer to deduce the bearing; in most cases all this can be done with an ordinary communications receiver and aerial-system. See DIRECTION-FINDER.

DIRECTIVE AERIAL. Aerial which radiates or receives most strongly in some particular direction or directions. A directive aerial may take many forms, the classic example being the inverted-L, which functions most effectively in the direction of the down-lead end. In general, those aerials used for work at the higher frequencies for which the aerial length bears some special relation to the wavelength are directive to a limited extent. Thus the simple half-wave dipole radiates or receives most strongly in directions at right-angles to its length and most feebly from its ends, giving a figure-of-eight polar diagram.

An array of such dipoles, placed end to end and suitably spaced in the same plane, produces a progressively more elongated figure as the number of elements is increased. Still further elongation, which means increased directive effect, can be obtained by placing reflectors behind each active element in order to weaken backward radiation and increase forward direction.

In another form, the aerial consists of a single element, normally a half-wave dipole, placed at the focal point of a reflector-system which may be a metallic surface, usually of parabolic form, or an assembly of passive elements so spaced and positioned as to produce a similar focusing effect; or a wire mesh surface can be used. Such an aerial-system radiates a more or less sharply focused narrow beam, such as is used for radar purposes, or for point-to-point communication on the higher frequencies. See AERIAL, AERIAL-ARRAY, HALF-WAVE DIPOLE, PASSIVE AERIAL, RHOMBIC AERIAL, YAGI AERIAL.

DIRECTIVE SENDING. Radiation which is at a maximum in some particular direction or directions. See DIRECTIONAL SENDER.

DIRECTIVE-SIGNALLING BEACON. Automatic radio sender which, by means of a directive-aerial system, radiates characteristic signals in a succession of known directions, so that ships or aircraft may obtain a bearing without the use of direction-finding apparatus. In a simple form, for instance, the beacon may radiate a revolving beam, carrying signals coded to indicate the bearing of the radiation at any given moment.

A distant observer has then only to listen to the beam as it sweeps by, and note the coding at the moment of maximum loudness. This is the instant when the beam is aimed directly towards him, and by referring to printed data on the particular beacon he can find out from what direction it radiates the particular code signal he has just noted, and thus find his bearing from the beacon. By repeating the process on a second beacon suitably placed, the observer can of course get an actual fix of his position.

DIRECTIVITY. Property of an aerial whereby radiation is concentrated into a particular direction or zone of directions, usually expressed as a solid angle. The directivity of an aerial is defined as the ratio of the power radiated into a specified solid angle to the power that would be radiated into that angle by some other reference aerial energized with the same power See DIRECTIVE AERIAL.

DIRECTLY-HEATED CATHODE. Synonym for FILAMENT.

DIRECTLY-HEATED VALVE. Valve with a filament-type cathode.

DIRECTOR AERIAL. See PASSIVE AERIAL, YAGI AERIAL.

DIRECT PICK-UP. Reception in which the wiring and components of a radio receiver act as an aerial, picking up strong signals directly. Good screening is the best preventive of this possible source of interference by nearby senders.

DIRECT RAY. Ray which has travelled over the earth's surface and not via the ionosphere. See GROUND RAY.

DIRECT RECEPTION. Synonym for DIRECT PICK-UP.

DIRECT RESISTANCE. See DIRECT IMPEDANCE.

DIRECT VIEWING. Term given to the system of cathode-ray television reception in which the viewer looks directly at the screen of the cathode-ray tube. In some receivers the cathode-ray screen is arranged to be scanned backwards, and the television image is viewed by means of a mirror set at an angle to the tube. In most receivers, however, direct viewing is employed. There is no technical preference between the two, and the choice depends on the style of cabinet, and its dimensions, and not on any technical advantage of one method over the other.

DIRECT WAVE. Synonym for GROUND WAVE.

DISC ANODE. Anode in the form of a disc. Certain forms of glow-tube have anodes in this form. The anode of a cathode-ray tube is also in the form of a disc. See ANODE.

DISC DISCHARGER. Synonym for ROTARY SPARK-GAP.

DISCHARGE LAMP. See ELECTRIC DISCHARGE LAMP.

DISCHARGER OSCILLATOR. Oscillator working on the principles of arc discharge. See DUDDELL ARC, POULSEN ARC.

DISCHARGE TUBE. See CATHODE-RAY TUBE, GAS-FILLED TRIODE.

DISC PRISM. System of mechanical scanning, invented by Jenkins of America, in which, instead of there being a spiral of holes or lenses in a metal plate to provide scanning, there are two prismatic discs. The discs are made of glass, and each is ground round its edge to act as a prism. The angle of the grinding varies continuously round the whole disc until it reaches the point at which the grinding started, so that there is a sudden change between the maximum and minimum angle, as shown in Fig. 20.

When passed through a prism, light is refracted, or bent. The amount of refraction depends on the angle of the prism. Thus, when a beam of light passes through one of the Jenkins's discs, it is refracted to an extent which depends on the angle of the prism at that point. Since the angle increases as the disc rotates, it is clear that if the beam is kept stationary, the light will be deflected an increasing amount as the disc revolves. In other words, the beam is made to scan in a straight line.

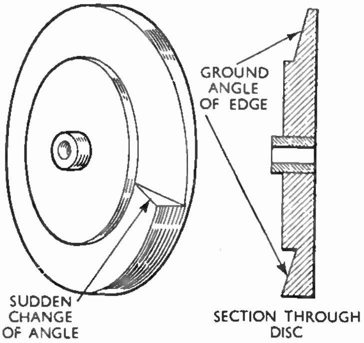


Fig. 20. Disc prism ground at the edge to give a continuously changing angle so that a beam of light is refracted progressively as the disc revolves.

At the point where the angle changes suddenly the beam is made to come back to the starting point, so that the disc causes a scan of the beam at a constant speed in one direction, with a sudden fly-back. Thus, one disc can be used for, say, a horizontal scan of the beam of light.

The other disc is arranged to rotate behind the first disc so as similarly to scan the beam, but in a vertical direction.

One disc obviously runs at a speed corresponding to the number of lines per second, and the other disc revolves more slowly at a speed corresponding with the number of picture frames per second. The second disc is sometimes referred to as an analyser.

DISCRIMINATOR. Circuit which produces an output voltage or current that is directly proportional to the frequency or phase of the signal applied to its input terminals, and has a sense depending on whether the frequency of the applied voltage is above or below a certain value. See AUTOMATIC TUNING-CONTROL, FREQUENCY DISCRIMINATOR FREQUENCY MODULATOR.

DISC SCANNER. Device for mechanical scanning in television, comprising a metal disc with a number of perforations in it. Light is directed on to the subject to be televised, and from this it is reflected on to a light-sensitive cell through the holes in the disc.

In the original 30-line system, devised by J. L. Baird, a large metal disc, with 30 holes arranged in a spiral in it, was made to rotate in front of the subject. As each hole came round, it moved across the subject, scanning a single line across it. Succeeding holes scanned lines successively below each other until the last hole, on the inside of the spiral, completed the frame, as shown in Fig. 21. Scanning was usually carried out in a vertical direction.

A similar disc was used at the receiver, a neon lamp, modulated by the transmitted signal, being employed as a source of light. This light was projected through the holes in the disc on to a viewing lens and the picture was viewed direct. Synchronization was carried out by a phonic wheel on the spindle of the disc, the wheel being used to retard or speed-up rotation in accordance with the synchronizing signal transmitted.

The original mechanical disc scanner employed a disc of about 16 in. diameter; the spiral of holes was arranged to give a picture of about 1½ in. by ⅝ in., the picture being magnified by a lens. The holes were square and only about $\frac{1}{48}$ in. across.

DISC SCANNING. System of scanning in television by means of a revolving disc with holes in spiral form near its edge (see DISC SCANNER).

As each hole passes across the scene, successive portions of it can be seen. If, as in the Baird system of television, a disc containing 30 holes is used, each hole provides a succession of strips of the picture in such a way as to break it up into 30 successive strips or lines, a complete scan being accomplished once every revolution.

If a lens is situated between a person looking at the disc and the scene so as to focus the light reflected from the scene through each hole on to his eye, and the disc is slowly turned, the observer will see the picture in successive strips until the whole picture has been covered. If the disc is speeded-up, the impression is not one of a succession of strips of picture, but that of a complete picture because of persistence of vision.

If the light falls on, instead of an observer's eye, a photocell while the disc scans the scene, as shown in Fig. 22, variations of electric current will be produced which can be transmitted through a wire or sent by radio.

At the receiver the process is reversed. The radio signal is made to modulate the light from some form of lamp. This light is passed through a disc similar to that used at the sender and the result, if the receiver disc scanner is synchronized with that at the sender, is that the picture is built up again in strips which, owing to persistence of vision, give the impression that the eye is looking at a complete picture.

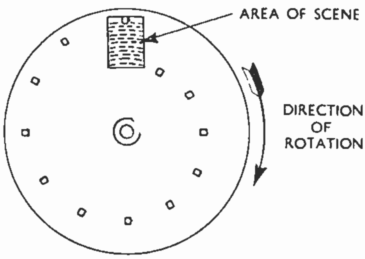


Fig. 21. Principle of the disc scanner invented by Nipkow; the holes, which scan the scene to be televised, are arranged in a spiral.

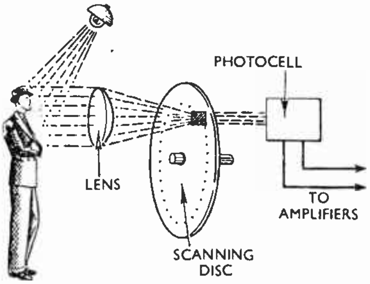


Fig. 22. Simplified diagram of disc scanning in which head and shoulders of the subject are illuminated and scanned by a 30-hole disc to give 30-line (low-definition) television.

Since the photocell reacts only to different intensities of light, and does not itself analyse the picture detail, it is obvious that, the more numerous the individual strips, or lines, into which the picture can be divided, the better the resultant definition. In other words, the greater the number and the smaller the size of holes, the clearer will be the detail in the received picture.

The present method of television used in Great Britain provides for a division of the scene into 405 lines. This would mean 405 holes on the scanning disc, if discs were used. Each hole would have to be accurately placed, and the disc would have to be relatively large. In fact, this system would be so clumsy that it would be next to impossible to achieve real success.

DISPLACEMENT CURRENT. Hypothetical current used to explain the transferring of voltages across the dielectric of a capacitor. A practical instance occurs in the apparent passage of an alternating current through a capacitor (see CAPACITANCE). There is, in fact, no actual conduction current through the dielectric of the capacitor, but current does continue to flow round the circuit; where it encounters the conductive interruption in the capacitor, it is regarded as a displacement current in the dielectric material

DISSECTOR MULTIPLIER. See IMAGE-DISSECTOR MULTIPLIER.

DISSECTOR TUBE. See IMAGE DISSECTOR.

DISSIPATION. Loss of power in any loss-producing circuit or component part thereof, such as a resistor or a capacitor with dielectric loss.

DISTANT RECEPTION. Reception of broadcasts at locations well outside the service area of the sender. Such reception is generally disappointing because of fading and noise. See LOCAL RECEPTION, SERVICE AREA.

DISTORTION. In a communication system, any difference, especially of waveform, that exists between the original and the reproduced signals. Although the various kinds of distortion are defined elsewhere under their respective names, they are, for convenience, classified here.

The first main type of distortion is that in which the gain (positive or negative) of the system varies with frequency; it is known as attenuation distortion. A particular case of it is aperture distortion. Effects similar to attenuation distortion, known as scale distortion, are produced in the process of hearing reproduced sound. Pre-emphasis, corrected elsewhere by de-emphasis, is deliberate attenuation distortion.

The second type, that in which the gain of the system varies with amplitude (usually instantaneous amplitude), is non-linear distortion. The various effects so produced are harmonic distortion, intermodulation distortion and amplitude distortion. Tracing distortion in gramophone reproduction is a particular example.

Amplitude distortion is sometimes deliberately introduced by a compressor and corrected elsewhere in contrast amplification by an expander.

The third category includes those forms of distortion that are not evident in the steady state, and so are called transient distortion. Particular forms are delay distortion, phase distortion and overshoot, or ringing. See also BUILDING-UP TIME.

In addition to the uses of deliberate distortion mentioned above, it is applied in order to obtain special waveforms, additional frequencies, etc.

Various kinds of visual distortion in television and oscillography include barrel distortion, keystone effect, origin distortion, pincushion distortion and trapezium distortion.

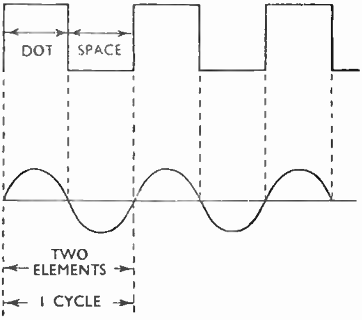


Fig. 23. Dot frequency of a code signalling system; a dot and a space together comprise one cycle.

DISTORTION FACTOR. Measure of total harmonic distortion, expressed as a percentage and given by:

$$100\sqrt{\frac{\text{sum of squares of amplitudes of harmonics}}{\text{square of amplitude of fundamental}}}$$

See HARMONIC DISTORTION.

DISTRIBUTED CAPACITANCE. Capacitance not concentrated in a capacitor but spread along, say, an aerial wire, between adjacent turns of an inductor winding, or between the wires of a feeder.

DISTRIBUTED CAPACITY. See DISTRIBUTED CAPACITANCE.

DISTRIBUTED INDUCTANCE. Inductance not concentrated in an inductor, but spread along, say, an aerial wire or feeder.

DISTRIBUTOR. In a telegraph system, a rotating device which automatically switches the intelligence to be conveyed to the different channels of a multiplex system.

DISTURBANCE. Synonym for INTERFERENCE.

DIVERSITY CHANNEL. Single channel in a diversity system.

DIVERSITY RECEPTION. Reception of a signal by means of a diversity system.

DIVERSITY SYSTEM. In telecommunication, any system by which a single signal is received either by the combination of, or selection from, a number of signals radiated by a group of individual senders. See CHANNEL DIVERSITY, DIVERSITY CHANNEL, DIVERSITY RECEPTION, RAY DIVERSITY.

DIVIDED CIRCUIT. In telegraphy, a circuit on which one or more message-channels are terminated at some point other than the terminal station of the circuit.

D-LAYER. Ionized layer in the atmosphere, believed to result from the impact of particle radiation emitted from the sun. This layer, considerably lower than either the E- or F-layer, often blocks short-wave communication, but appears sometimes to improve conditions on long waves.

dn. Abbreviation for DECINEPER.

DOT FREQUENCY. Half the number of elements in a code signalling system. This definition will be better appreciated by reference to Fig. 23 and by remembering that a space in a code is considered as an element of the code. See MORSE CODE.

DOUBLE AMPLITUDE. Peak-to-peak value of an alternating current or voltage. In practice, double amplitude is simply twice the peak value, that is the sum of the positive and negative voltage swings. Double amplitude is illustrated in Fig. 24.

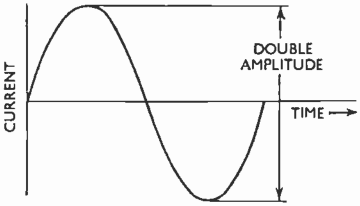


Fig. 24. The double amplitude of an alternating current or voltage is the peak-to-peak value, as shown.

DOUBLE-BEAM CATHODE-RAY TUBE. Cathode-ray tube in which the electrodes are so arranged that the electron beam from a single cathode is divided into two separate paths. It permits the simultaneous investigation of two variable quantities. See CATHODE-RAY TUBE, OSCILLOGRAPH.

DOUBLE-CURRENT SYSTEM. Telegraph system in which signals are transmitted by reversing a current that is normally on the line during transmission.

DOUBLE-DETECTOR RECEPTION. See SUPERHETERODYNE RECEPTION.

DOUBLE-DIAMOND AERIAL. See RHOMBIC AERIAL.

DOUBLE DIODE. Diode with two anodes insulated, and sometimes shielded, from one another; and usually, but not invariably, with a

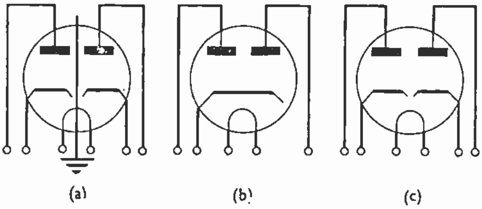


Fig. 25. Symbolic representation of three forms of double diode: (*a*) with separate indirectly heated cathodes and a shield between the diodes; (*b*) with a common cathode, and (*c*) as (*a*) but without shield.

common cathode. Fig. 25 shows a double diode. Exactly the same illustration applies to a full-wave rectifier circuit. The double diode is also used for full-wave rectification in detection circuits and is then known as a full-wave detector. For detection, the anodes are very small and are sometimes in the form of small discs. See DIODE, DOUBLE-DIODE TRIODE, FULL-WAVE RECTIFICATION.

DOUBLE-DIODE HEPTODE. Multiple valve comprising two diode anodes and a heptode electrode assembly surrounding a common cathode. See DIODE, HEPTODE, MULTIPLE VALVE.

DOUBLE-DIODE HEXODE. Multiple valve comprising two diode anodes and a hexode electrode assembly surrounding a common cathode. See DIODE, HEXODE, MULTIPLE VALVE.

DOUBLE-DIODE PENTODE. Multiple valve comprising two diode anodes and a pentode electrode assembly surrounding a common cathode. See DIODE, MULTIPLE VALVE, PENTODE.

DOUBLE-DIODE TETRODE. Multiple valve comprising two diode anodes and a tetrode electrode assembly surrounding a common cathode. See DIODE, MULTIPLE VALVE, TETRODE.

DOUBLE-DIODE TRIODE (or tetrode, pentode, hexode or heptode). Valve having the three or other appropriate number of normal electrodes and two small auxiliary diode anodes, the cathode being common both to the normal electrodes and to the diode anodes. Fig. 26 is a way of showing the double-diode triode diagrammatically.

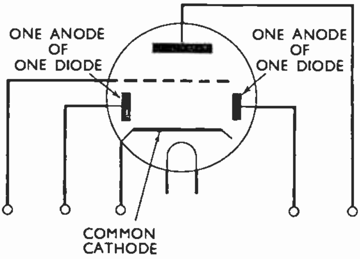


Fig. 26. Diagrammatic representation of a double-diode triode. The same (indirectly heated) cathode is used for the triode as for the two diodes.

The arrangement was designed to economize in cathode power and space generally. The one emitter suffices for the valve proper, as well as for the double diode. In many circuits the diode and other valve are used in cascade; thus detection and amplification, for example, can be carried out in the one valve. See DETECTOR, DIODE, DOUBLE DIODE, TRIPLE DIODE.

DOUBLE FEEDBACK. Circuit arrangement in which feedback occurs within a valve amplifier by way of two separate loops.

DOUBLE-FREQUENCY OSCILLATOR. Oscillating system in which two sets of oscillations are produced, each having a separate frequency.

DOUBLE-HUMP EFFECT. Double-peaked resonance effect (Fig. 27), normally resulting from tight coupling between two circuits. See BAND-PASS TUNING, COUPLING.

DOUBLE IMAGE. Effect produced on a cathode-ray tube screen where a second image, usually much weaker than the main image, is seen. The image is displaced by a slight amount from the main image, but is similar to it in every detail. The cause is reflection of the received radio signal from some object—usually near the receiving location.

Since the reflected signal has to travel a path longer than that of the direct signal, it arrives a fraction of a second later. It then passes through the receiver and modulates the cathode-ray tube, with the result that a "repeat" of the image just built-up is provided and a "ghost," or double image results.

Large metal buildings, gasholders and passing aircraft frequently cause this effect. Sometimes little can be done about it, but often an aerial with a reflector carefully arranged to make it sharply directive can bring about a cure.

DOUBLE-POLE SWITCH. Switch for the simultaneous making or breaking of two separate paths of a circuit. See SWITCH.

DOUBLE-PURPOSE VALVE. Valve which may be connected up in two different ways to perform two distinct functions. Thus almost any valve may be so termed; for example, any triode may be connected up as an amplifier or as an oscillator, and any R.F. pentode can be used for radio-frequency or audio-frequency amplification.

The term "double-purpose" may also be applied to a valve containing two sets of electrodes with separate cathodes or a common cathode. Such a valve virtually consists of two valve structures in one envelope and the two electrode assemblies can be independently connected to external circuits. This is, however, more correctly termed a MULTIPLE VALVE (q.v.). See also DOUBLE DIODE, DOUBLE-DIODE TRIODE.

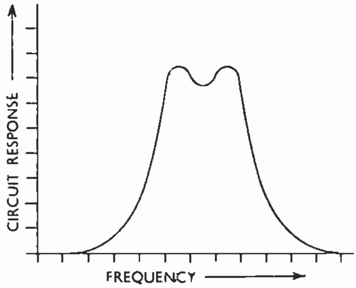


Fig. 27. Double-humped resonance curve which results from a tight coupling between two tuned circuits.

DOUBLER. Abbreviation of FREQUENCY-DOUBLER.

DOUBLE REACTION. Synonym for DOUBLE (positive) FEEDBACK.

DOUBLE RECEPTION. Synonym for DIPLEX RECEPTION.

DOUBLE RETROACTION. Synonym for DOUBLE (positive) FEEDBACK.

DOUBLE-SIDEBAND TRANSMISSION. Method of radio-telephony transmission in which both the bands of frequencies produced by modulation are radiated.

DOUBLET. Synonym for HALF-WAVE DIPOLE.

DOUBLE-WAVE RECTIFICATION. Synonym for FULL-WAVE RECTIFICATION.

DOUBLING. Abbreviation of FREQUENCY-DOUBLING.

DRAMATIC CONTROL PANEL. Equipment consisting of faders, switches and so on, used by a producer of radio drama to get a combined effect by the use of separate studios. The system is no longer used.

DRIVE. See MASTER OSCILLATOR.

DRIVEN SENDER. Sender the radiated frequency of which is determined by a master oscillator.

DRIVER. Stage of amplification providing the signal-frequency power for the following stage.

DRIVING-POINT IMPEDANCE. Ratio of the voltage at any two points on a network to the current flowing at these two points. See IMPEDANCE, NETWORK.

DRUM SCANNER. A mechanical system of television scanning which overcomes the drawback of the scanning disc, namely, the serious loss of light due to the light beam having to pass through small holes in the disc.

The mirror drum consists of a narrow drum, around the circumference of which are arranged small rectangular mirrors, the number corresponding with the number of lines required for the television system.

Each mirror is set at a different angle and scans one line of the picture. The change in angle between each mirror produces the successive lines across the picture required for scanning as indicated in Fig. 28.

The mirror drum has to be supplied with a source of light that is modulated by the received picture signal, this being reflected by the drum on to a screen. Synchronization of the drum with the sender is difficult and requires a powerful synchronizing signal, just

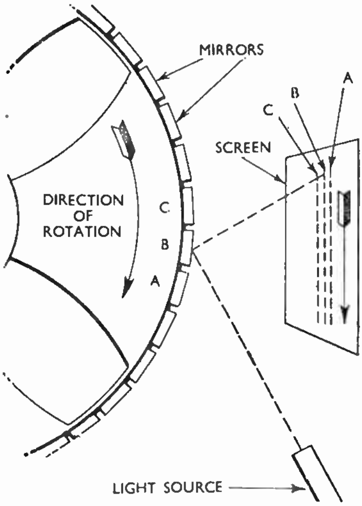


Fig. 28. Principle of the drum scanner; each mirror on the drum is tilted in relation to its neighbours and scans a light path slightly displaced from that scanned by the preceding mirror.

as the synchronizing of a disc scanner necessitates a powerful signal. This signal operates some form of phonic wheel which can pull the drum into step if it tends to revolve too fast or too slowly.

DRY BATTERY. Term frequently used to describe a battery of dry cells. See DRY CELL.

DRY CELL. Any primary cell in which the electrolyte is in the form of a paste rather than a liquid. The commonly used dry cell is a form of Leclanché cell. The construction of a dry cell of the type widely employed in high-tension batteries, portable torches, etc., is shown in Fig. 29. The container is made of zinc and forms the negative electrode, the positive electrode being a carbon rod capped with thin brass.

The manganese-dioxide de-polarizer is in contact with the carbon rod and held in a semi-permeable bag of linen or canvas. The paste electrolyte is formed from a sal-ammoniac solution and gelatine or flour. In some forms of cell, the de-polarizer is mixed with the paste electrolyte, the bag not being used.

DRY-CELL BATTERY. Number of dry Leclanché cells connected in series or in parallel. Such batteries are extensively used for H.T. and L.T. supplies for portable receivers. See LECLANCHÉ CELL.

DRY ELECTROLYTIC CAPACITOR. Form of electrolytic capacitor in which the electrolyte is of paste-like consistency and is "dry" in comparison with the aqueous, or "wet," type. See FIXED CAPACITOR.

DRY ELECTROLYTIC CONDENSER. Synonym for DRY ELECTROLYTIC CAPACITOR.

DRY-PLATE RECTIFIER. Synonym for METAL RECTIFIER.

D.S.C. Abbreviation, in reference to conductors, for double-silk covered.

D.S. & ENAM. Abbreviation, in reference to conductors, meaning double-silk covered and enamelled.

DUAL AMPLIFICATION CIRCUIT. Circuit in which the same valve ampli-

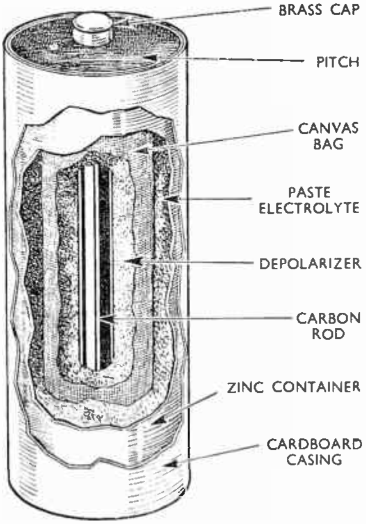


Fig. 29. Dry cell, partly cut away to show a typical form of construction.

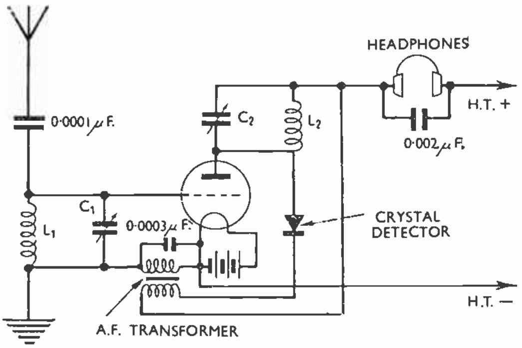


Fig. 30. Simple dual-amplification, or reflex, circuit in which the valve amplifies the signal, first at radio frequency, and then again at audio frequency after rectification by a crystal detector.

fies the signal twice—once at radio and once at audio frequency. Such circuits had a considerable vogue in the early nineteen-twenties, for at that time the general-purpose triode was comparatively expensive, and needed half to three-quarters of an ampere of filament current at 6 volts. As large accumulators were used for filament supply—no mains valves being then available—there was an obvious advantage in making each valve do as much work as possible.

Fig. 30 illustrates one of the earliest and simplest dual or reflex circuits; points to be noted are the fixed capacitor in series with the aerial lead—a common device before the general adoption of the untuned, coupled aerial—the absence of grid bias, and the use of a simple tuned-anode circuit with the triode.

In this form of circuit an amplified version of the radio-frequency signal appears in the anode circuit, where it is first rectified by the crystal detector and then reflexed back to the grid circuit by the audio-frequency transformer. An audio signal is thus impressed on the anode current and causes an amplified version to be heard in the headphones. The fixed capacitors of 0·0003 and 0·002 μF are to by-pass radio-frequency signals.

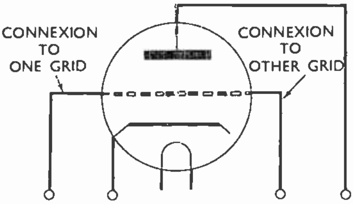


Fig. 31. Diagrammatic representation of a dual-grid valve (triode); the two grids are concentric.

DUAL-GRID VALVE. Valve with two concentric control grids. Either of the control grids (Fig. 31) may be connected to the anode, or both grids may be connected together. In the former case, the valve acts as a triode with a low amplification factor; in the latter case as one with a high amplification factor.

Two grids connected together shield the cathode from the anode more effectively for a given value of grid current, than does one closely wound grid. Thus two valves, one with a single and the other with a dual grid, may each give the same high amplification factor, but the dual-grid valve draws less grid current. This makes it particularly suitable for class-B valve operation. See WUNDERLICH VALVE.

DUDDELL ARC. System of producing alternating currents by connecting a D.C. supply across an arc discharger, and shunting the arc with an oscillatory circuit; it was discovered by Duddell in 1900. In Fig. 32 a constant D.C. supply is maintained across the arc by means of the battery, through the resistor R_0 and inductor L_0. The frequency f of the alter-

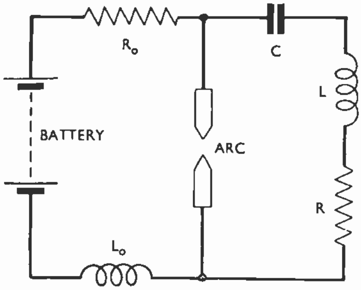


Fig. 32. Circuit for the Duddell-arc method of producing alternating current from a D.C. source. The frequency of A.C. thus derived is limited, however, to about 10,000 c/s.

nating currents in the oscillatory circuit C, L, R is obtained from $\omega = \frac{1}{\sqrt{LC}}$, where $\omega = 2\pi f$.

The Duddell arc produced low power and its frequency was limited to about 10,000 c/s. These limitations were imposed by the ionization-change rate in the arc. At higher frequencies, there was insufficient time for ionization changes to take place, and the negative resistance of the arc (upon the maintenance of which oscillation depended) became too small to maintain the circuit in oscillation. See POULSEN ARC.

DULL-EMITTER VALVE. Valve having a cathode which glows a dull red. Early in radio history, all valves had filament types of cathode made of tungsten wire which had to be heated to a high temperature to give the required emission; these filaments glowed brightly. With the introduction of the oxide-coated filament, and later of indirectly heated cathodes, less heat was required for adequate emission and the illuminating properties of valves were reduced. A distinction was then made between the old bright-emitter and the new dull-emitter valves. The term is now obsolete because nearly all valves are dull emitters and those that still use tungsten filaments often have water-cooled anodes which mask the light. See BRIGHT-EMITTER VALVE, EMISSION INDIRECTLY HEATED CATHODE.

DUMB AERIAL. Synonym for ARTIFICIAL AERIAL.

DUMMY AERIAL. Any network simulating the electrical characteristics of an aerial. The simplest form of dummy aerial is a closed resonant circuit with capacitance, inductance and resistance equal to the effective values of the capacitance, inductance and resistance (including the radiation resistance) of the aerial it simulates. The exact equivalent is seldom realized in practice because the inductance and capacitance of an aerial are distributed whereas those of a closed circuit are "lumped." In testing senders it is convenient to use dummy aerials so that waves shall not be radiated. See CLOSED CIRCUIT.

DUODYNATRON. Valve oscillator in which two resonant circuits are connected to the inner grid and anode of a tetrode, the outer grid being maintained at a higher positive potential than the anode in order to provide a negative A.C. anode resistance which maintains oscillation in both the resonant circuits.

DUOLATERAL COIL. Synonym for DUOLATERAL-WOUND COIL.

DUOLATERAL WINDING. Method of winding coils for certain types of resistor, inductor and transformer in which two wires are wound on to a former simultaneously and side by side with the object of making two coil sections of identical inductance. The method is shown in the illustration (Fig. 33). It is sometimes known as "bifilar" winding. In making resistors, either the inner or the outer ends of each wire of the pair are joined together and the other pair are connected to the terminals so that, magnetically, the two sections are in series opposition; this forms a "non-inductive" resistor.

There is, however, considerable capacitance between the two wires, which appears as a shunt across the resistance, so that the method is limited to low values of resistance and to low frequencies. Some improvement may be achieved by connecting in series a number of sections wound in this way. If there are n sections, then the shunt capacitance is reduced in the ratio 1 : n^2. Other methods of winding, such as the Ayrton-Perry (see FIXED RESISTOR), have a wider field of use.

For making balanced inductors and balanced windings of transformers the method has advantages. In such cases, the outer end of one wire of the pair is joined to the inner end of the other wire of the pair, so that, magnetically, the two sections are in series aiding. The joint serves as an accurate centre-tap and the two halves are substantially equal in inductance. There are numerous applications where such a feature is desirable. For example, an inductor used as an inductive ratio arm in a measuring bridge; or a hybrid coil or other transformer where a high degree of balance is required between the two halves of one winding.

As a rule, it is impedance balance rather than inductance balance that is important; and for this reason the method is limited for the most part to audio frequencies. At very low frequencies, resistance inequalities between the two wires upset the balance; at higher frequencies it is almost impossible to ensure that the capacitance between the two wires is uniformly distributed along the length. In practice, the capacitance tends to be greater at one end than the other and therefore the effective capacitances across each half of the coil do not balance.

DUOLATERAL-WOUND COIL. Coil in which two wires are wound on to a former simultaneously and side by side with the object of obtaining identical inductance in two sections of the coil. See DUOLATERAL WINDING.

DUOLATERAL-WOUND INDUCTOR. Inductor having a duolateral-wound coil. See DUOLATERAL WINDING.

DUOLATERAL-WOUND RESISTOR. Wire-wound resistor having a duolateral-wound coil. See DUOLATERAL WINDING.

DUPLEX BALANCE. Network, used in connexion with line telegraphy, designed to simulate the impedance presented by a line. See BALANCING NETWORK.

DUPLEX OPERATION. In radio-communication, two-way

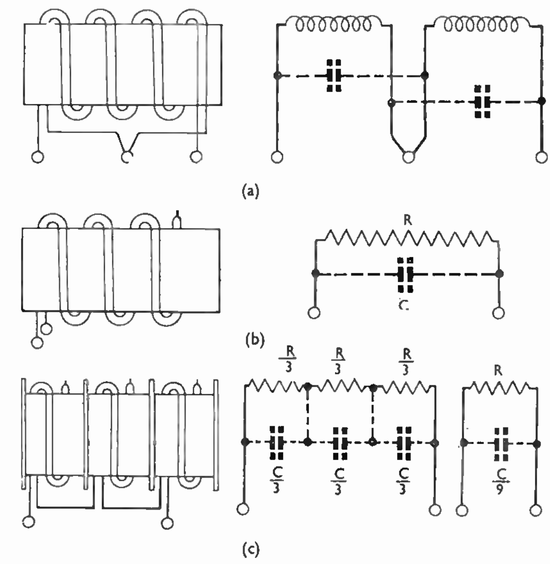


Fig. 33. Use of duolateral winding, showing the effect of capacitance between a pair of wires: (*a*) inductive connexion for balanced inductors and transformers; (*b*) non-inductive connexion for resistors, and (c) non-inductive series connexion for reducing self-capacitance.

transmission in which signals may be communicated simultaneously in both directions over the same circuit and using the same frequency band.

DUPLEX SYSTEM. System of communication employing DUPLEX OPERATION (q.v.).

DUPLEX VALVE. Two similar valve structures having a common cathode and housed in a single envelope. A diagrammatic representation of a duplex valve is given in Fig. 34. Such a valve is useful for BALANCED VALVE-OPERATION (q.v.).

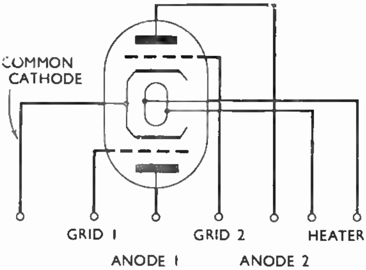


Fig. 34. Diagrammatic representation of a duplex valve. Anodes 1 and 2 and grids 1 and 2 are insulated from each other; the cathode, however, is common to both halves of the valve.

DUST CORE. Magnetic core, for an inductor or transformer, moulded from finely divided and insulated particles of a magnetic material, such as iron or nickel-iron alloy. The isolation of the particles greatly reduces the eddy-current loss, particularly at high frequencies, and their separation reduces the effective hysteresis loss, but, at the same time, also diminishes the effective permeability.

The powder is mixed with a suitable insulating binder, such as synthetic resin, and is formed at high pressure in a mould of the required shape. The

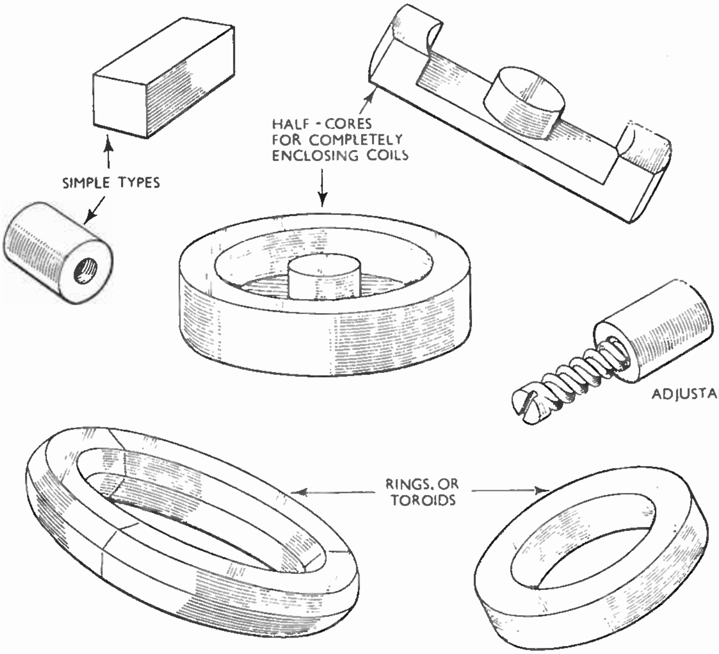


Fig. 35. Dust-cores, consisting of a powdered magnetic material and an insulating binder, are moulded in a variety of shapes, of which these are examples.

mixture is varied to suit the frequency of application as follows:

Frequency	*Material*	*Effective Permeability*
Audio	Nickel-iron	100
Carrier (on line)	,,	40
..	Pure electrolytic iron	15
Radio	,,	4

Typical core shapes are illustrated in Fig. 35. See DUST-CORED INDUCTOR, FIXED INDUCTOR, IRON LOSS, VARIABLE INDUCTOR.

DUST-CORED COIL. Synonym for DUST-CORED INDUCTOR.

DUST-CORED INDUCTOR. Inductor having a core moulded from finely divided and insulated particles of a magnetic material such as powdered iron. The object of the magnetic core is to reduce the size of the inductor for a given inductance or to increase its Q-factor.

The purpose of finely dividing the material is to reduce the losses due to the core to a small value, even at radio frequencies. At these frequencies, the core usually consists of a rod of pressed iron-dust lying along the axis of the coil. The core may be moved along the axis of the coil to vary the inductance. This type of variable inductor is used in so-called permeability tuning. At lower frequencies, a toroidal-wound inductor on a ring-shaped core is often used. See DUST CORE, FIXED INDUCTOR, VARIABLE INDUCTOR.

DWARF WAVE. Term sometimes used to describe a radio-wave of 1–10 mm., that is, within a frequency range of 300,000–30,000 Mc/s. Work on such waves is at present mainly experimental, but, in general, the propagation characteristics are similar to those of centimetric waves. See CENTIMETRIC WAVE.

DYNAMIC CHARACTERISTIC. Valve characteristic relating variable quantities when the valve is arranged to function as an amplifier, frequency-changer, detector, oscillator or for any other purpose. The ordinary or static valve characteristic is a graph relating measured electrode voltages and electrode currents; thus no resistors may be used in external circuits, because these would affect electrode voltages and so make it impossible to compare valves one with another on a common basis.

The designer of valve circuits may be helped, nevertheless, by knowing how electrode currents vary with electrode voltage when resistors or impedors form part of an external circuit. Fig. 36 shows the typical change that might be noticed in a graph of grid volts plotted against anode current due to the existence of a resistor in series with the H.T. supply and the anode. Such a characteristic is known as a dynamic characteristic because it would show how the anode current varies with grid volts under operating conditions. See VALVE CHARACTERISTIC.

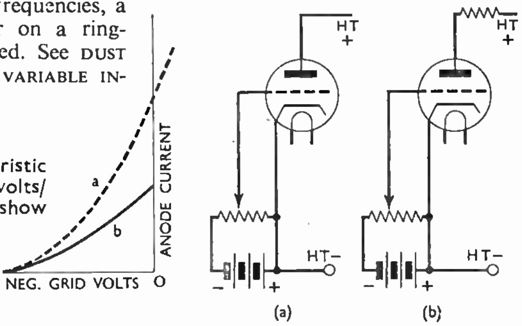


Fig. 36. Dynamic characteristic of a valve. The grid-volts/anode-current curves show respectively the general form that the characteristic takes when the valve is connected as at (*a*) and as at (*b*).

DYNAMIC CONDUCTANCE. Synonym for SLOPE CONDUCTANCE.

DYNAMIC IMPEDANCE. Synonym for REJECTOR IMPEDANCE.

DYNAMIC RESISTANCE. Synonym for SLOPE RESISTANCE.

DYNAMO. Term sometimes used for direct-current generator. See D.C GENERATOR.

DYNAMOMETER. Instrument for measurement of power. Its operation depends upon the fact that, if current is passed in the same direction through two adjacent coils or wires, one of which is fixed and the other free to move, attraction will occur between the coils or wires and cause the movable member to rotate. The extent of its rotation is proportional to the degree of attraction between it and the fixed coil or wire and hence to the current flowing. The pointer is attached to the movable coil and, by causing this to move across a calibrated scale, measurements are obtainable.

DYNAMOTOR. Machine for changing the voltage of a D.C. supply: sometimes called a rotary transformer It consists of an armature having two separate windings with independent commutators, but only one magnetic field which may be either shunt- or compound-wound. The machine thus combines the functions of motor and generator within a single casing.

DYNATRON. Triode or tetrode in which two adjacent electrodes are made positive with respect to the cathode, that nearer the cathode being more positive than the other. Over a certain range of potential, secondary emission from the outer electrode (usually the anode) causes the anode current to fall when its potential is increased, this indicating a negative anode A.C. resistance.

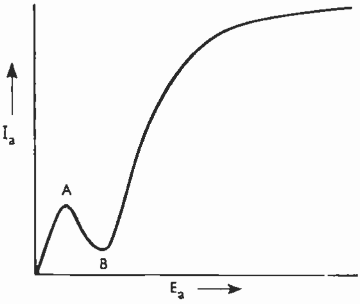


Fig. 37. Anode-current/anode-volts graph of a tetrode showing the kink *AB*, characteristic of the dynatron

In the I_a–E_a curves of a tetrode valve (Fig. 37), the region *AB*, known as the "tetrode kink," illustrates this negative resistance.

DYNATRON OSCILLATOR. Valve oscillator in which the negative A.C. anode resistance of a dynatron is used to maintain oscillation in a resonant circuit included in the anode circuit. See OSCILLATOR.

DYNE. Unit of force in the system having the gramme, centimetre and second as its basic units. A dyne is that force which will apply an acceleration of one centimetre per second per second to a mass of one gramme.

DYNODE. Electrode in a valve which provides secondary electron emission.

E

EARPHONE. Single headphone used as a receiver on a telephone instrument. See HEADPHONE.

EARTH. Terminal or circuit point the potential of which cannot be changed. The potential of the terminal or point is called zero. The term may also describe a steady-potential point to which a number of circuits is joined so that all points so joined have the same potential. An earth is any means by which a conductive connexion is made to a point at zero or steady potential; for example, an earth may be formed by a water pipe in a house.

A typical phrase is "this point is connected to earth" or "is earthed"; what is meant is that the point is connected to a conductor which eventually finds its way to some earth system (see EARTH SYSTEM). In practice, an earth may be raised in potential owing to the fact that it is not directly connected to an earth system but is at some distance from it. This long connexion has impedance, and it is thus possible to raise the potential of that end of the earth conductor which is remote from the earth system.

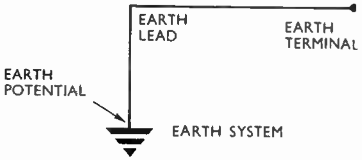


Fig. 1. As the earth lead connecting the earth terminal to the earth system has impedance, the earth terminal may have a potential difference to zero or true earth potential.

Fig. 1 shows the meaning of earth when it is truly a terminal which is part of an earth system. In the great majority of cases, it is not essential to bring parts of circuits to zero potential so long as they are maintained at a steady potential. Thus, Fig. 2a shows how, in a valve amplifier, several connexions are taken to a

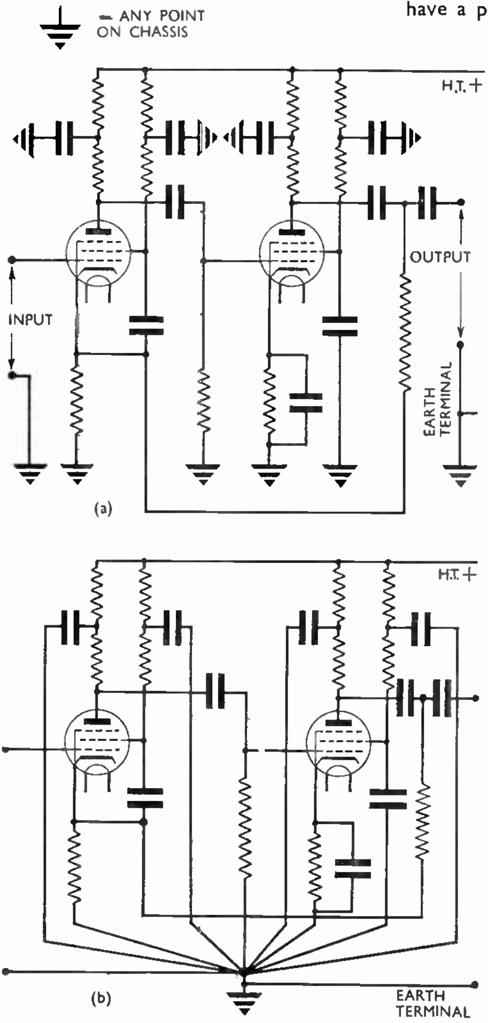


Fig. 2. Diagrams showing earth connexions. In (*a*) circuit points are joined to the chassis; this is not good practice in high-gain amplifiers operating at radio frequencies because differences of potential may be set up between parts of the chassis. In (*b*) all parts of the circuit are connected to a single point.

chassis, which is connected to the earth terminal. It is assumed, very often without justification, that no difference of potential can exist between different points on the same metal chassis. This is a dangerous assumption, particularly when the frequencies of the currents amplified are very high.

Thus Fig. 2b shows a good, and sometimes essential. practice, in which all the points that ought to be at the same potential are brought to a common terminal which is itself connected to one point on the chassis. Provided that this common earth point is connected to the earth lead or earth terminal, even though this may vary in potential, all the circuits in the amplifier will then rise or fall in potential together. This will not matter, because it will not result in any common-impedance coupling between the circuits themselves.

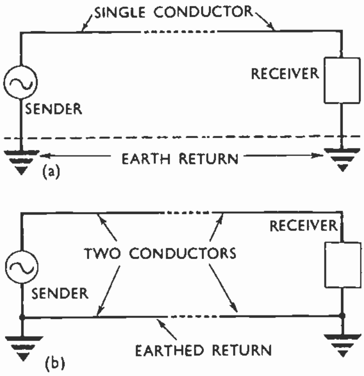


Fig. 3. Earth return (*a*) as distinct from the earthed-return circuit (*b*), in which a second conductor is used.

In many cases, a radio receiver will work perfectly satisfactorily without an earth connexion. This is because there is a point—usually the chassis—to which all common connexions are made. The aerial potential varies above and below the potential of the chassis, which is steadied to some extent either by its greater capacitance to earth or because of a connexion to the mains which approximates to an earth. See EARTH CIRCUIT, EARTHING, EARTH LEAD, EARTH POTENTIAL, EARTH TERMINAL.

EARTH CIRCUIT. Connexion or connexions leading from apparatus, or equipment, to the earth system. See EARTH.

EARTH CURRENT. Current flowing in the conductor or conductors forming the earth circuit. See EARTH, EARTH CIRCUIT.

EARTHING. Term denoting the connexion of a circuit point or points to earth. See EARTH, EARTH SYSTEM.

EARTH LEAD. In a radio sender or receiver, the single conductor which connects the earth terminal of the apparatus to the earth system. See EARTH, EARTH SYSTEM.

EARTH POTENTIAL. Potential of a point or terminal which cannot be sensibly changed in potential. The term may also be used to describe the potential of a point of common connexion in an apparatus or equipment which has the lowest potential and the least impedance with respect to a terminal at the earth potential. See EARTH.

EARTH-RETURN CIRCUIT. In a transmission line, the part of the circuit which is completed by conduction of currents through the earth itself. A line and an earth-return is an example of an unbalanced transmission line (Fig. 3). See BALANCING AERIAL, EARTH, UNBALANCED CIRCUIT, UNBALANCED TRANSMISSION LINE.

EARTH SYSTEM. Any system of conductors or conductive material in direct physical connexion with the earth. It is of great importance in most electrical circuits to ensure that certain circuit points shall be held at the same, and nearly zero or virtually zero, potential (see EARTH).

It is justifiably assumed that the potential of the globe on which we live cannot be raised in potential by any electrical system devised by man. This does not mean that localized points cannot be raised in potential; indeed it is possible, with a sensitive amplifier, to detect differences in potential between conductors stuck in the ground a few yards apart.

The assumption that the earth cannot be raised in potential is perhaps better expressed by saying that if the earth is connected to one terminal of a source of alternating e.m.f. and a non-earthed system is connected to the other, then the unearthed system will vary in potential by far greater amounts than the earthed. Thus the aerial of a sender may execute large variations of potential; but the earth system, to which the earth terminal of the sender is connected, stays at virtually the same potential because it is in direct contact with the earth.

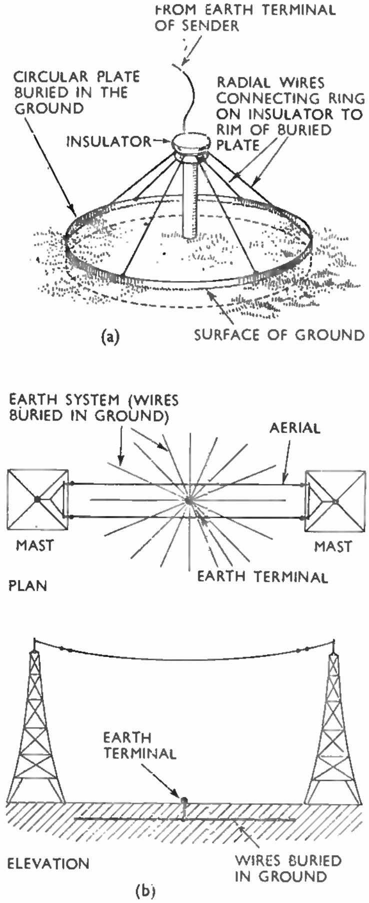


Fig. 4. Two forms of earth system: in (*a*) a circular plate is buried one or two feet in the ground with its upper rim projecting; in (*b*) wires are laid radially along furrows in the ground.

There is inevitably some resistance formed in making connexion between the conductive system buried in the earth and the earth itself. Power is wasted in senders by this resistance and everything possible is done to minimize it. Fig. 4 shows two typical earthing systems used at senders. The loss due to high-resistance earth systems in receiving aerials is of no particular importance, provided the receiver embodies a radio-frequency amplifier.

The signal-to-noise ratio is the chief factor determining the efficiency of reception always provided that the receiver has adequate amplification. The earth system, good or bad, generally makes little or no difference to signal-to-noise ratio, although a bad earth sometimes increases noise. With a crystal receiver—one which does not embody valves—it is very important that the earth system shall be efficient, because the received signal strength is proportional to the currents set up in the aerial, and these may be reduced by a high-resistance earth.

Earth systems are used in other applications of electrical engineering; telephone exchanges, power stations, cable stations and so forth all require a good earth. See AERIAL, COUNTERPOISE, EARTH.

EARTH TERMINAL. Terminal joined to the conductor or conductors which terminate on an earth system. See EARTH, EARTH LEAD, EARTH SYSTEM.

EARTHY. Term describing any circuit point which has the least impedance or the smaller of two impedances to earth. In other words, a circuit point which is not likely to vary in potential so

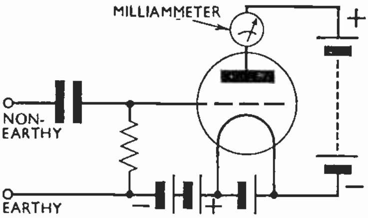


Fig. 5. The earthy terminal of a valve voltmeter is that which has the greater capacitance to earth.

much as another which is part of the same circuit, but which may not be directly connected to an earth lead or to earth. One of the terminals of a valve voltmeter may be labelled "earthy." This is the terminal which is connected to cathode or to the filament in a battery valve. This terminal of the voltmeter has, therefore, a greater capacitance to earth than the grid and its potential cannot, therefore, be varied so readily as that of the grid (Fig. 5).

The voltmeter may be used to determine the potential between two circuit points. The potential at one of these points may vary less than that of the other and it is preferable to connect the earthy terminal of the voltmeter to the circuit point showing the least variation in potential. Thus in measuring the potential between the anode and cathode of a valve using current feedback, it is advisable to connect the earthy terminal of the voltmeter to the earthy terminal (i.e. the cathode) of the source (Fig. 6).

Put in another way, an earthy terminal has a lower impedance to earth than a non-earthy one and is therefore connected to points having an effectively lower internal resistance. See EARTH, EARTH SYSTEM.

EBONITE. Vulcanized rubber, frequently used as insulating material. It should not be used in contact with copper, which it attacks.

ECHO. Wave which has been reflected and reaches a certain point later than the wave which travels in a straight line between the source and the point in question.

ECHO PATH. Path followed by RADIO ECHO (q.v.).

ECHO ROOM. Highly reverberant room or chamber used to add artificial echoes to sounds. The room contains a loudspeaker and a microphone; the output from the studio microphone is taken through two paths, one directly to a mixer and the other via the loudspeaker and microphone in the echo room to the same mixer (Fig. 7). Thus the sounds made in the studio are repeated by the loudspeaker in the echo room, and are given a reverberant character. The reverberant sounds are picked up by the echo microphone. Thus the mixer has two inputs containing the same basic character; one represents the normal and small reverberation of a studio, the other a highly exaggerated reverberation.

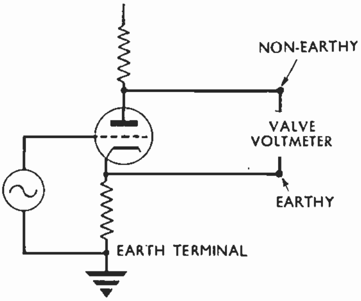


Fig. 6. Although the cathode of the valve shown is not earthed, it has less impedance to earth than has the anode; hence the earthy terminal of the voltmeter is connected to the cathode.

The adjustment of the mixer determines the proportion of reverberation in its output. This is judged by the operator of the mixer according to the nature or sequences of the programme. The mixing of a constant but small reverberation with orchestral music may produce a more pleasing effect; in dramatic presentations, a twist of the mixer may, in effect, take a character from outdoors into a cathedral or from an apparently distant part of a room to a place seemingly closer to another character in the same room.

ECHO-SUPPRESSOR. In a four-wire telephone channel, a circuit comprising valves and relays designed to permit speech currents to pass in one direction only. The device prevents the speaker from hearing echoes of his voice reflected from the distant end of the circuit.

EDDY CURRENT. Circulating current induced in a mass of conducting material by a moving or varying magnetic field. The effect may be compared with the action of a transformer in which currents are induced in the secondary winding by the varying magnetic field due to the primary current. The secondary currents represent a load on the primary circuit, and eddy currents similarly represent a load on the source of magnetic field. Eddy currents may cause serious losses in high-frequency apparatus; they compel the designer to pay careful attention to the spacing between all inductors and any metallic objects, especially screening compartments (Fig. 8).

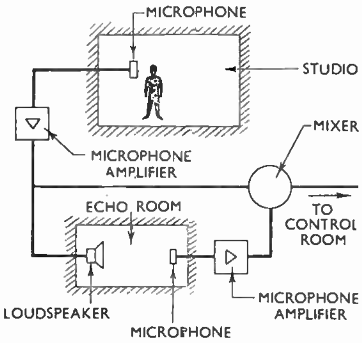


Fig. 7. Output from the studio microphone finds two paths to the mixer, one direct and one through a highly reverberant echo room. The mixer can be adjusted to mix to any desired degree the direct studio output with a reverberant version of the output.

Even in low-frequency A.C. practice there are circumstances in which the eddy currents must be minimized, notably in the iron cores of transformers, inductors and electromagnets. These are built up of thin laminations, more or less insulated from each other, so that eddy currents of appreciable magnitude cannot build up in the core.

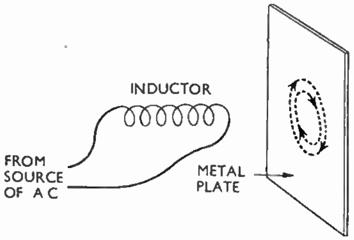


Fig. 8. Circulating eddy currents, due to electromagnetic induction, are set up in a metal plate located near the end of a winding in which alternating currents are flowing.

Although eddy current is generally regarded as a nuisance to be suppressed, it has certain useful applications as in the eddy-current brake, in which circulating currents are used to absorb power from a driving motor and so enable the machine to be tested under load.

EDISON ACCUMULATOR. Synonym for nickel-iron-alkaline accumulator which was invented under the direction of Thomas Edison.

EDISON EFFECT. Emission of charged particles from a heated filament which makes conduction of electricity possible between an anode and the filament. Edison was one of the first technicians to demonstrate the conduction of electricity through a rarefied gas.

Early types of electric lamps used a carbon filament, and it was noticed that, after a time, the bulb blackened on the inside of the glass. In investigating this phenomenon, Edison proved, by putting a small conductive plate in a lamp and making a connexion to it, that charged particles were emitted from the filament. It was seen that the path between the plate (anode) and the filament (cathode) gave unilateral conduction. In effect Edison made the first diode.

The apparatus for demonstrating the Edison effect (with which most physics laboratories were provided) was used by Sir Ambrose Fleming to make a D.C. instrument measure radio-frequency current; this led to the first diodes used for detection of radio signals, and the Lee de Forest audion. See AUDION, DIODE, RECTIFIER.

EFFECTIVE BAND WIDTH. Arbitrarily chosen frequency-band characterizing the performance of a band-pass or band-stop filter and within which the filter attenuation does not vary more than a specified amount. A typical attenuation characteristic of a band-pass filter is shown in Fig. 9; f_1 and f_2 are the true cut-off frequencies, but owing to loss in filter elements, unmatched termination and so on, the attenuation is greater at these frequencies than at the middle of the pass-band.

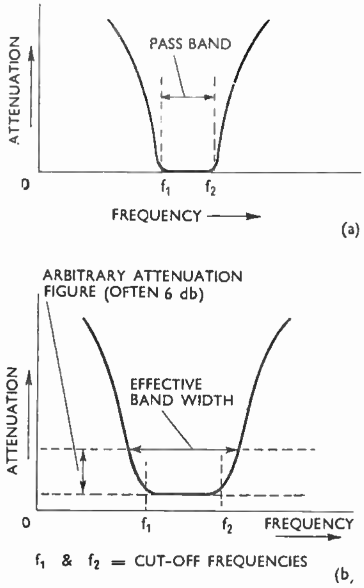


Fig. 9. Attenuation/frequency characteristic of (*a*) an ideal band-pass filter, and (*b*) that which results in practice, the effective band width being chosen as the example shown.

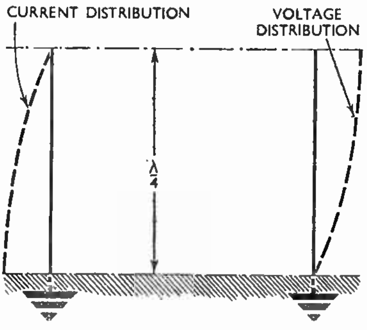


Fig. 10. Current and voltage distribution in a quarter-wave vertical aerial. Effective height is governed by the fact that current is not uniform and has the effect of reducing the amount of power radiated, making the aerial equivalent to a shorter one with the same current.

The effective band width might be specified as the frequency band lying between frequencies at which the attenuation is, say, equal to or less than 6 db. or 3 db. Fig. 9a and Fig. 9b bring out these points in diagrammatic form. For a band-stop filter, the limit is given as so much less than a maximum attenuation. See BAND-PASS FILTER, BAND-STOP FILTER.

EFFECTIVE HEIGHT. Height that an earthed, vertical wire should attain in order to radiate the same field along the horizontal as is present if the wire carries a current that is constant along its entire length, and of the same value as at the base of the actual aerial. The formula for the power radiated by a vertical quarter-wavelength aerial is:

$$\text{Total power radiated} = \frac{320\,\pi^2\,h^2\,I^2}{\lambda^2},$$

where h is the height of aerial in

metres, I the r.m.s. value of aerial current in amperes and λ the wavelength in metres.

The formula is based on the assumption that the amplitude of the aerial current is the same at all points along the aerial. This is not the case in practice, the current distribution usually being sinusoidal, as shown in Fig. 10. In such a case, the effective height may be taken as the actual height multiplied by the ratio of the average value of the current to its peak value, which, for sinusoidal distribution, is $2/\pi$. For other types of distribution, similar allowance must be made. See AERIAL, AERIAL-ARRAY, RADIATION.

EFFECTIVE RESISTANCE. Total equivalent resistance of a circuit or component of a circuit, consisting of the ohmic resistance of the conductor or conductors plus the effect of circuit losses, expressed as a resistance.

EFFECTIVE VALUE. Value of a direct current which has the same heating effect as the alternating current in question. It is usually expressed as a fraction of the peak value. The effective value is the root-mean-square value of the alternating current.

EFFICIENCY. In general, the ratio of the energy obtained from any device to the energy applied to it. It is often expressed as a percentage. For example, the efficiency of a dynamo is the ratio of the electrical energy developed at the output terminals to the mechanical energy necessary to give this output. The anode efficiency of a valve is the ratio of the alternating power developed in the anode load to the power drawn by the anode circuit from the H.T. source.

EIGHT-ELECTRODE VALVE. Synonym for OCTODE.

E-LAYER. Region of ionized gases at a variable height of some 50–90 miles above the surface of the earth. The ionization appears to be mainly due to direct electron bombardment from the sun, although ultra-violet radiation probably accounts for some of the ionization The mean height at which the ionization exercises an appreciable effect upon radio-wave propagation is about 70 miles, but the lower limit is not sharply defined and varies from winter to summer and between night and day.

The E-layer is responsible for the reflection of most waves in the medium-frequency band, and for reflection at the lower frequencies of the high-frequency band. It is less intensely ionized than the F-layer, but because the gas pressure is higher, it is more stable and less dependent upon the sun's influence than is the F-layer. See IONOSPHERE, IONOSPHERIC REFLECTION, IONOSPHERIC REFRACTION, KENNELLY-HEAVISIDE LAYER, MEDIUM-FREQUENCY WAVE.

ELECTRICAL COMMUNICATION. See TELECOMMUNICATION.

ELECTRICAL RECORDING. Recording sound by electrical, as distinct from acoustical, means. It implies the use of a microphone, an amplifier and a recording machine for the conversion of sound waves into electrical energy, and use of that energy to produce a sound track on a moving medium, for example, cellulose-coated discs, steel tape or film.

Recording systems used by radio broadcasting organizations fall into three groups: gramophone, including direct-disc recording; magnetic recording; and sound film.

The original acoustic system of gramophone recording had two inherent disadvantages. The first was that it required the performers to be grouped around a horn, which made satisfactory musical balance difficult and limited the choice of programme material. The second disadvantage was that frequency response was limited to a range of approximately 300 to 3,000 c/s.

Modern technique, which simulates that of broadcasting studios, has developed along two lines, namely, commercial recording for the production of gramophone records, and direct-disc recording for immediate playback.

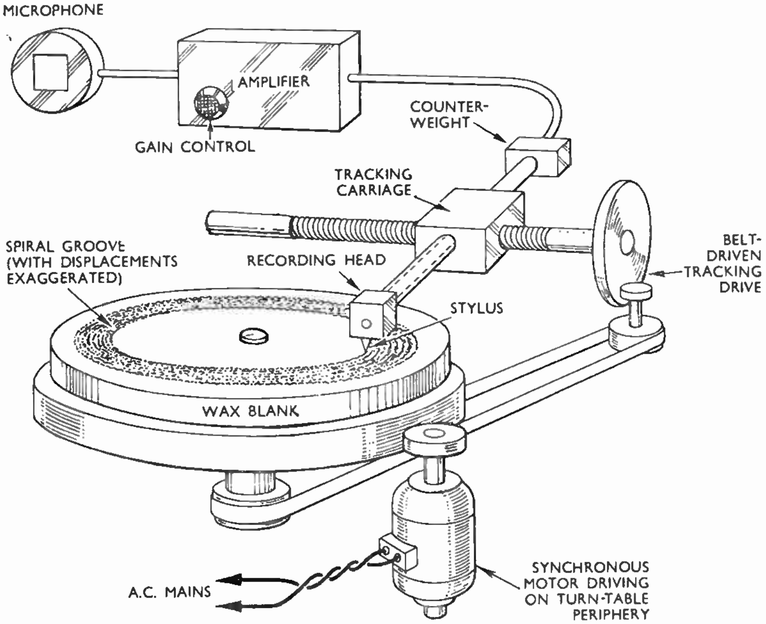


Fig. 11. Essentials for electrical gramophone recording. Sounds picked up by the microphone are amplified and applied to the recording head, the stylus of which vibrates, forming a sound track on the rotating wax blank. The tracking carriage is moved slowly across the blank, producing a spiral groove.

The essential principles of both systems are illustrated in Fig. 11. Sounds produced in the studio are converted by a microphone into electrical pressure variations which are amplified and passed to the recording head. The latter is designed on the principle of a gramophone pick-up, and may have a moving-iron, moving-coil or piezo-electric movement.

The head is fitted with a cutter or stylus (usually of synthetic sapphire) which, when signals are applied to the head, vibrates laterally at the frequency of the initial sounds. The turntable, on which is placed the recording material, a soft wax blank or a cellulose-coated disc, is driven at a constant speed (33⅓ or 78 r.p.m.) by an electric motor. The recording head is mounted on a carriage which, when the turntable revolves, moves radially across the blank. (On some machines this process is reversed, the head being stationary and the turntable platform moving.)

When the recording head is lowered, the stylus contacts the blank, cutting a groove in the form of a spiral. If, at the same time, signals are applied to the head, the lateral vibration of the stylus causes the groove to be displaced on either side of its mean position, the displacements having a wave form similar to that of the sounds picked up by the microphone.

The distance between adjacent grooves is regulated by the speed at which the recording-head carriage traverses the radius of the blank. The groove spacing is called the pitch and is usually adjustable. If the pitch is too fine, adjacent grooves will overlap at large stylus displacements, breaking the continuity of the spiral and rendering satisfactory reproduction impossible.

From the recorded wax blank, copies are produced by processing. A metal master copy is first produced from the recorded wax blank by electro-plating processes and, from the master, metal stampers are made. A heated plastic, e.g. clay, shellac and copal, is placed under a stamper and the final record produced. A thousand or more copies can be made from each stamper.

In the direct-recorded disc system, wax blanks are not used, because they deteriorate rapidly if played back before processing. Therefore, a direct-recorded disc is made of a harder material; it consists of a rigid base (metal, glass or other suitable material) coated with a lacquer produced from cellulose nitrate.

The hardness of this lacquer must be such that it can be cut easily by a sapphire stylus, and must also be capable of reproduction by an ordinary gramophone needle without the groove being damaged. The thickness of the coating must be uniform and sufficient to prevent the tip of the stylus from penetrating to the metal base (0·008 in. meets normal requirements). If copies are needed, a direct-recorded disc may be processed to produce the stamper.

A modern transportable disc-recording equipment is shown in Fig. 12. Power supplies for the turntable and amplifier-valve filaments are taken from a heavy-duty, 12-volt battery. The amplifier H.T. supply is derived from a motor-generator, housed in the supply unit below the amplifier and driven by the 12-volt battery.

Essential requirements for faithful recording are: full-range audio-frequency response, low-percentage harmonic distortion, adequate volume range and constant turntable speed. The first two of these requirements are functions of microphone, amplifier and recording-head design; the third largely depends upon adequate groove spacing, and the fourth is usually achieved by the use of a synchronous motor.

Magnetic recording was first used by Poulsen for recording morse signals

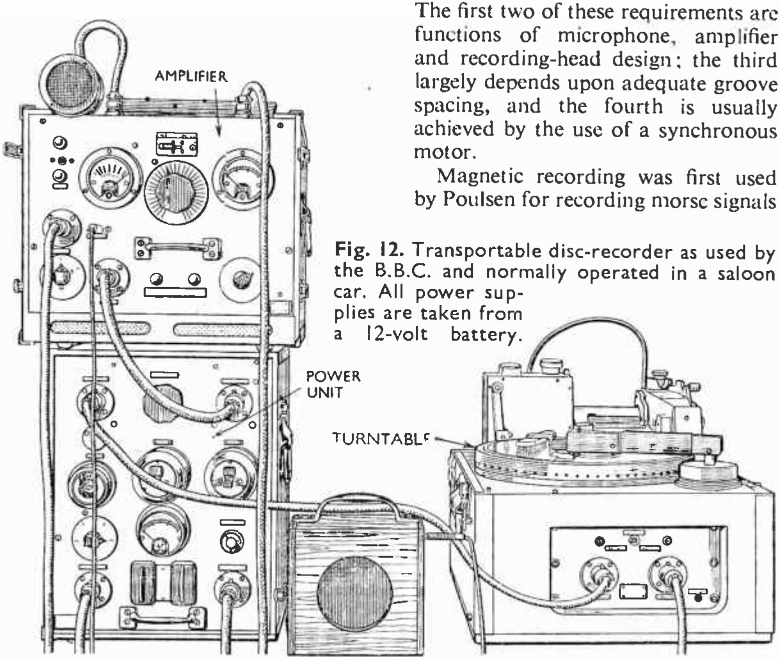


Fig. 12. Transportable disc-recorder as used by the B.B.C. and normally operated in a saloon car. All power supplies are taken from a 12-volt battery.

at high speed over a telegraph system. In this system, the signals at the receiver could be recorded magnetically and reproduced at a slower speed. A steel wire was driven through a solenoid, the electric current through the solenoid being interrupted by a morse key. This is a simple application of the law of magnetic induction, the moving steel wire becoming magnetized by the current in the solenoid.

The principle was applied to the recording of sound in 1924 by Stille, a German engineer. A steel tape (Fig. 13) was first magnetized to saturation by a magnetizing, or wiping, head energized by direct current, and then partially de-magnetized by another head connected to a D.C. source and to the output of the recording amplifier. When signals were applied to this head, the intensity of magnetization on the tape after it had passed by the pole-piece varied on either side of the value fixed by the D.C. de-magnetizing field; that is, it depended on the combined effect of the D.C. and A.C. signal currents passing through the coil of the head.

By passing the tape through a reproducing head, the magnetic variations were transformed into electric potentials, which were then amplified and applied to a loudspeaker, producing signals corresponding to the original sounds picked up by the microphone.

A machine, designed to operate on these principles and called a Blattnerphone, was used in 1930 by the B.B.C. for recording and reproducing broadcast programmes. Since that date other machines have been developed, notably the Marconi-Stille (British), the Magnetophon (German) and a small, portable steel-wire recorder (American).

Sound is recorded on film either by a photographic process or by an inscribing process. Where it is required to synchronize sound signals with a motion picture, it is customary to use a photographic film as the recording material. Light is projected through a narrow slit on to the film, and either the intensity of the light or the width of the beam is varied about a mean value at the frequency of signals applied to the recording amplifier.

If the light intensity is varied, the method is known as *variable-density* recording. It is achieved by

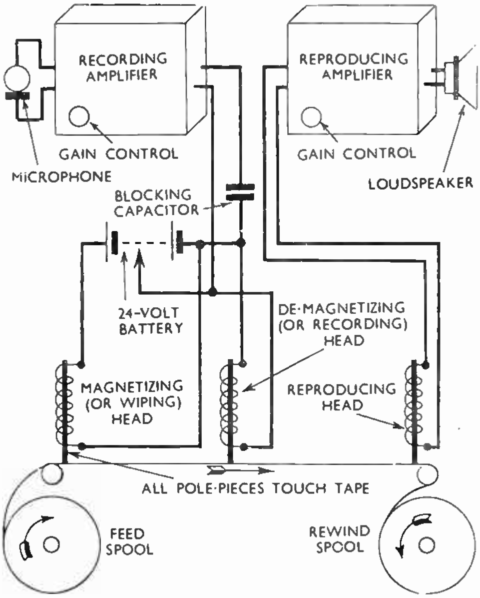


Fig. 13. Schematic diagram of magnetic recorder. The tape, first magnetized to saturation, is partially de-magnetized by D.C., the degree of de-magnetization being varied by signals applied to the recording head. The sound track is invisible and consists of magnetic variations on the steel tape, such variations being proportional in frequency and amplitude to the applied signals.

connecting the output of the recording amplifier to a light valve, the function of which is to vary the amount of light passing through a narrow slit interposed between the light source and the film. The light intensity at any instant will, therefore, be proportional to the signal e.m.f.s, and there is recorded on the moving film a sound track having density variations which correspond to the wave form of the sounds picked up by the microphone.

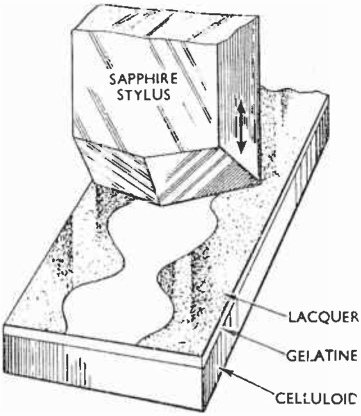


Fig. 14. In the Philips-Miller recorder, perpendicular movement of the cutter inscribes a variable-area track in the thin opaque lacquer. The gelatine layer prevents the cutter tip from becoming blunted on the celluloid base of the film.

With the *variable-area* method, the output of the recording amplifier is connected to a device which operates a mirror galvanometer, the light source being reflected on to a slit of constant width. The intensity of the light remains constant, but the width of the reflected beam varies in direct relationship to the values of the signal e.m.f.s. Thus the film is exposed to a light beam of constant intensity but of variable area.

With both these systems the sound is reproduced from the track by driving the film through a sound gate, comprising a narrow slit on one side of which is an exciter lamp and on the other a photocell. E.m.f.s are thus produced at the output of the photocell which are proportional to the variations in density or area of the sound track.

In the Philips-Miller system of film recording, a variable-area sound track is inscribed by a sapphire stylus on film coated with a very thin layer of black mercuric sulphide (Fig. 14). The movement of the stylus is in a direction perpendicular to the surface of the film and is controlled by the signals from the recording amplifier. A sound track having a width proportional to the signal e.m.f. is therefore cut on the film. Reproduction in this case is also by means of a photocell.

Comparisons between different recording systems must be based on overall performances; deficiencies in recording are often compensated for in reproduction.

A good recording system should have an over-all frequency response which is level between 30 and 10,000 c/s, harmonic distortion less than 1 per cent, and a driving speed constant to within 0·2 per cent. A further requirement is a signal-to-noise ratio of at least 40 db.

In gramophone recording, such a frequency response is possible on the outer diameter of the disc, but there is a tendency to reduced reproduction of the higher audio frequencies as the centre of the disc is approached. This is because the cutting speed decreases as the diameter decreases. The recorded wavelengths in inches are equal to $\pi dn / 60f$, where d is the diameter of the disc in inches, n the turntable speed in r.p.m. and f the signal frequency in cycles per second.

At the smaller diameters, the wave forms become cramped, and the reproducing needle finds difficulty in tracing the recorded grooves. This tracing distortion may be partly offset by progressively increasing the amplitude of the cutting stylus movement at high frequencies as the centre of the disc is approached. This is called radius compensation. It becomes ineffective at very small diameters and may cause serious harmonic distortion.

Harmonic distortion may be as low as 2 per cent for a well-designed disc recorder, and speed constancy is assured when synchronous motors are used to drive the turntable. Signal-to-noise ratio is higher for direct-recorded discs than for pressings, and the former offer the facility of immediate playback.

Magnetic recording avoids tracing (high-frequency) loss; the tape travels at a constant speed of approximately 90 metres per minute throughout recording. A frequency response of 100–7,000 c/s is obtainable. Harmonic distortion is low, but surface noise, except in the case of the Magnetophon, tends to be high. The tape can be de-magnetized and used many times.

Film recording generally has good frequency response and surface noise characteristics, and provides a high-fidelity system where running costs are a secondary consideration. It is the most suitable system for synchronizing sound recording with moving pictures, the picture and sound tracks being carried on the same film. See ELECTRICAL REPRODUCTION, GRAMOPHONE PICK-UP, MARCONI-STILLE RECORDER, PHOTOCELL.

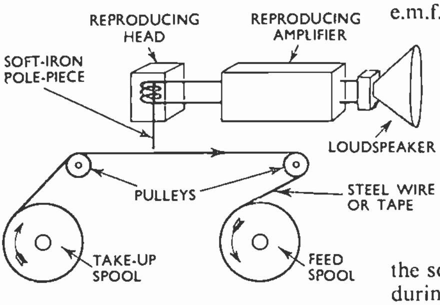


Fig. 15. Principles of magnetic sound reproduction. The sound track is in the form of magnetic variations on the wire; when the wire is driven past the pole-piece, alternating e.m.f.s corresponding to the recorded signals are induced in the coil and reproduced through an amplifier.

ELECTRICAL REPRODUCTION. Reproduction of any recorded sound track by electrical as distinct from acoustical means. Excepting gramophone records, all modern recording systems are reproduced electrically; gramophone records are reproduced by either electrical or acoustical means.

The essential requirements for electrical reproduction are: a reproducing head, means of moving the recording medium, an amplifier, and a loudspeaker or headphones. The type of reproducing head varies with different systems: a pick-up for gramophone records or discs (see GRAMOPHONE PICK-UP), a simple electromagnet for magnetic recordings, and a photocell for sound films.

The principle of reproduction applied to magnetic recordings is that of simple electromagnetic induction. The reproducing head consists of an electromagnet, the pole-piece of which either touches or lies in close proximity to the tape (Fig. 15). As the tape is driven past the pole-piece, the latter is subjected to the varying degrees of magnetization imparted to the tape during the recording process.

The varying flux densities, thus set up in the pole-piece, cause alternating e.m.f.s to be induced in the coil, such e.m.f.s having the same frequency as the sounds applied to the microphone during recording. The e.m.f.s are amplified electronically, the amplifier being equalized to correct for the inherent attenuation distortion of the tape.

With most magnetic recording systems, reproduction is marred by high surface noise, the signal-to-noise ratio corresponding roughly to that of a badly worn gramophone record. In recent years, the development of

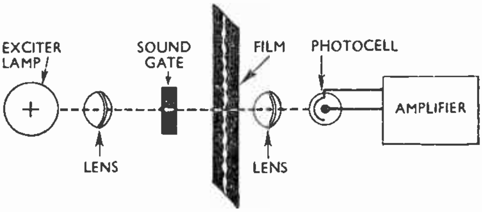


Fig. 16. Principles of sound reproduction from film by the Philips-Miller system. Variations in sound-track area cause varying intensities of light to fall on the photocell, producing small e.m.f.s which are then amplified.

plastic tapes, impregnated with iron oxide, has contributed to the reduction of surface noise (see MAGNETIC RECORDING, MARCONI-STILLE RECORDER).

The reproducing, or sound, head used for transforming the sound track of a film into electrical energy consists of a light source, a focusing lens, a sound-gate, consisting of a narrow slit, and a photocell. A schematic arrangement of the Philips-Miller system is given in Fig. 16. Similar principles apply to the reproduction of photographically recorded films.

Light is projected through the lens and slit on to the moving film. As the film is driven past the slit, the photocell is subjected to light of varying intensity, the variations corresponding to the density or area variations exposed on the film during the recording process. Since electronic emission within the cell is proportional to the quantity of light falling upon it, minute alternating e.m.f.s are produced between anode and cathode of the cell, the frequency of such e.m.f.s being similar to those of the recorded sounds.

As with other systems, the output of the reproducing head is connected to an equalized amplifier to obtain the correct frequency response and output volume.

In photographic sound films the original copy is a negative, from which numerous copies are taken for commercial distribution. In this process, some attenuation distortion is introduced owing to a decrease in definition, and signal-to-noise ratio is reduced because of the relatively coarser grain of the positives. In the Philips-Miller system, used for recording radio programmes, this problem does not arise, because processing is unnecessary. See ELECTRICAL RECORDING, PHOTOCELL.

ELECTRICAL RESONANCE. Condition in a circuit containing inductance and capacitance in which the inductive and capacitive reactances are equal. In general, there is only one frequency at which this condition exists, and it is known as the RESONANT FREQUENCY (q.v.). In a simple series circuit of inductance and capacitance the impedance is a minimum at resonance; in a parallel circuit of inductance and capacitance the impedance is a maximum at resonance.

ELECTRIC COMPONENT. Electric-field component of an electromagnetic wave. The principles of the radiation of electromagnetic energy are based on the laws that a moving magnetic field creates an electric field, and that a moving electric field creates a magnetic field. The created field at any instant is in time-phase with its parent field, but is at right angles to it in space. See POLARIZATION, RADIATION.

ELECTRIC CURRENT. Drift of free electrons through the substance of a conducting material. See CONDUCTOR, ELECTRON.

ELECTRIC DISCHARGE LAMP. Synonym for GLOW-TUBE.

ELECTRIC DISPLACEMENT. Synonym for ELECTRIC FLUX DENSITY.

ELECTRIC ELEMENT. Conductor which is heated by the passage of a current; the element is used for heating purposes, as in an electric cooker or iron. It is usually made of nickel-chrome resistance wire. The term "electric element" may also be used to denote any resistor, capacitor or inductor forming part of an electrical network.

ELECTRIC FIELD. Region, occupied by forces emanating from an electric charge, or in which they act. For example, an electric field exists in the space between two adjacent charges of opposite sign. See ELECTROSTATICS.

ELECTRIC FIELD STRENGTH. Intensity of an electric field at a particular point measured by ascertaining the force of attraction or repulsion on a unit charge placed at the particular point in the field.

ELECTRIC FLUX. Lines of electric force composing an electric field. See ELECTRIC FIELD, ELECTRIC FLUX DENSITY, ELECTRIC FORCE.

ELECTRIC FLUX DENSITY. Measure of the intensity of an electric field integrated over some particular unit of area in the field, this unit of area being assumed to be arranged so as to intercept the field of force at right angles to its direction of action.

ELECTRIC FORCE. Force of attraction or repulsion exerted between adjacent electric charges.

ELECTRIC OSCILLATIONS. Oscillations in an alternating-current-operated circuit, the frequency of such oscillations being determined by the constants of the components forming the circuit. The oscillations may have constant amplitude, as in the case of continuous-wave radio sending, or the amplitude may decrease rapidly, as in a spark sending system. See OSCILLATION.

ELECTRIC RELAY. Device used in electrical circuits by means of which the current in one circuit opens or closes contacts which control the flow of current in a second circuit.

ELECTRIC SCREEN. Conducting electrode, in the form of a solid plate or a fine wire mesh, used to reduce or prevent the penetration of an electric field into a certain region. When used to prevent the establishment of an electric field between two conductors, the screen is placed between them and is earthed, resulting in cancellation of the capacitance between them. See SCREENING.

ELECTRIC STRENGTH. Ability of an insulator to withstand an electric stress without breakdown. A measure of the electric strength of a material can be obtained by determining the voltage at which breakdown occurs under standardized conditions.

ELECTRIC STRESS. Stress occurring in an insulating material when a difference of electrical potential exists across it.

ELECTRIC WAVE. Synonym for ELECTROMAGNETIC WAVE.

ELECTRODE. Conductive element, of a valve, which may emit, collect or control the flow of electrons or ions and electrons. The electrodes of a valve are usually insulated one from another, but in pentode valves the suppressor grid may be connected to cathode or control grid inside the valve.

Electrodes of a valve are an anode, a cathode, which emits electrons, and grid-type electrodes, which may collect electrons or control their flow between cathode and anode. The control grid is often operated at a negative potential with respect to cathode and does not, in such circumstances, collect electrons; but it does, according to its potential, exercise the greatest control on the electron current. See ANODE, CATHODE, ELECTRODE CURRENT, ELECTRODE IMPEDANCE, GRID, SLOPE RESISTANCE, VALVE.

ELECTRODE A.C. CONDUCTANCE. Synonym for SLOPE CONDUCTANCE.

ELECTRODE A.C. RESISTANCE. Synonym for SLOPE RESISTANCE.

ELECTRODE CAPACITANCE. Capacitance of an electrode to earth or to other specified electrodes. In valve operation, the capacitance of one electrode to another or to earth may have a profound effect upon the behaviour of the valve (see AMPLIFIER, MILLER EFFECT, TETRODE). The limitations imposed upon the highest frequencies of waves that may be amplified by a resistance-capacitance amplifier are largely due to electrode capacitance.

The introduction of the screen grid into the triode to form the tetrode was made to minimize the effects of the capacitance between control-grid and anode. The decrease of control-grid impedance, as the frequency of the wave applied to this electrode is increased, is due to the grid-electrode capacitance.

Electrode capacitance decreases as the dimensions of the electrode structure, hence valves are made smaller. This reduction of overall size does not affect the amplification factor of a valve, and small valves may thus be used for amplifying waves of very high radio frequency. The leads connecting the valve pins to the electrodes add to electrode capacitance, and special designs are necessary in valves used for the amplification of waves of very high frequency. See AMPLIFIER, FOOTLESS CONSTRUCTION, MILLER EFFECT, TETRODE.

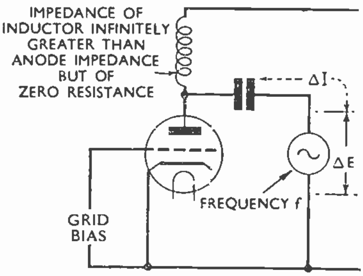


Fig. 17. If the impedance of the inductor is assumed to be infinite and its resistance zero, electrode (anode) impedance may be determined from knowledge of the frequency *f*, the alternating voltage ΔE and the current ΔI.

ELECTRODE CONDUCTANCE. See SLOPE CONDUCTANCE.

ELECTRODE CURRENT. Current flowing to and from an electrode. The electrode current forms part of the space current. The current used to heat the cathode is not termed an electrode current, but filament or heater current. See SPACE CURRENT.

ELECTRODE D.C. CONDUCTANCE. Reciprocal of ELECTRODE D.C. RESISTANCE.

ELECTRODE D.C. RESISTANCE. Resistance measured by the ratio of electrode voltage to electrode current. See SLOPE RESISTANCE.

ELECTRODE DIFFERENTIAL CONDUCTANCE. See SLOPE CONDUCTANCE.

ELECTRODE DIFFERENTIAL IMPEDANCE. See ELECTRODE IMPEDANCE.

ELECTRODE DIFFERENTIAL RESISTANCE. See SLOPE RESISTANCE.

ELECTRODE DISSIPATION. Power dissipated in the form of heat by the electrode of a valve (see ANODE DISSIPATION). The anode electrode usually dissipates the greatest heat due to bombardment by electrons, but other electrodes also rise in temperature; for instance, the cathode, as well as the anode in a glow-tube, is liable to get hot due to positive ion bombardment. Screen grids, when carrying a large current, may become hot also. In general, however, if the anode can safely dissipate the heat developed, no other electrode gets hot enough to be damaged. Thus in a cooled valve, the cooling of the anode helps to keep the other electrodes at a safe temperature. See COOLED VALVE, RATED ELECTRODE DISSIPATION.

ELECTRODE IMPEDANCE. Impedance between an electrode of a valve and another specified point in a circuit. Sometimes the reference point is not mentioned (as in the phrase "anode impedance"); in such cases the point may be taken to be at cathode or earth potential. The impedance is obtained by varying the electrode potential by a small amount ΔE and by noting the corresponding change in electrode current ΔI; the impedance is then given by $\Delta E/\Delta I$.

It is important that all electrode voltages and currents should have their normal values when the measurement is made; otherwise the value of impedance obtained is not that which applies under working conditions. There is usually a small capacitance between any one electrode of a valve and the other electrodes. Similarly, most electrodes have a small value of inductance. These two properties of the electrode can modify the impedance, but their effects are negligible at very low frequencies.

At low frequencies, therefore, ΔI is in phase with ΔE and the impedance is predominantly resistive. As frequency is raised, however, the effects of electrode capacitance and inductance become more important, and ΔI is no longer in phase with ΔE. Division of ΔE by ΔI thus gives a complex quantity indicating that the impedance now has a reactive component.

The basis of a method of measuring the anode impedance of a valve is shown in Fig. 17. A battery connected to the grid applies the normal value of grid bias to the valve. The anode is connected to the H.T. supply through an inductor, and an A.C. generator applies potentials to the anode by way of a fixed capacitor. The generator applies the small alternating potential ΔE at the frequency at which the anode impedance is to be measured.

The reactance of the capacitor must be very small at the frequency of measurement, compared with the anode impedance, so that the full value of ΔE reaches the anode. Since the valve and the inductor are effectively in parallel, the alternating current ΔI taken from the generator includes two components, one of which flows through the anode-cathode path of the valve and the other through the inductor. The latter current is made very small by choosing an inductor which, at the frequency of measurement, has a reactance very large compared with the impedance of the valve. As ΔI is current in the valve only, the impedance is given by $\Delta E/\Delta I$.

ELECTRODE POTENTIAL. Voltage acting between an electrode and earth, or the voltage acting between any two specified electrodes if neither is earthed. The anode voltage is the voltage between anode and cathode; the control-grid voltage may be that between control grid and earth, or between grid and cathode. If nothing is stated to the contrary, the electrode potential or voltage is the potential difference between the electrode and earth.

ELECTRODE RESISTANCE. See SLOPE RESISTANCE.

ELECTRODE SLOPE-CONDUCTANCE. See SLOPE CONDUCTANCE.

ELECTRODE SLOPE-RESISTANCE. See SLOPE RESISTANCE.

ELECTRODE VOLTAGE. See ELECTRODE POTENTIAL.

ELECTRODYNAMIC LOUDSPEAKER. Synonym for MOVING-COIL LOUDSPEAKER.

ELECTRODYNAMIC MICROPHONE. Synonym for MOVING-COIL MICROPHONE.

ELECTROLYTE. Liquid or paste used in voltaic cells. The conduction of electricity through the electrolyte between electrodes in contact with it takes place by virtue of a transfer of ions from one electrode to another. See ACCUMULATOR CELL.

ELECTROLYTIC CAPACITOR. Form of capacitor in which the dielectric is deposited on one or both of the metallic electrodes by electrochemical means. See FIXED CAPACITOR.

ELECTROLYTIC CONDENSER. Synonym for ELECTROLYTIC CAPACITOR.

ELECTROLYTIC DETECTOR. Early form of detector based on the polarization of an electrolyte. The circuit arrangement is shown in Fig. 18. When the battery is connected to the cell, the current which flows through the liquid breaks up the molecules, due to the process of electrolysis, and a thin film of gas is formed over the electrodes, after which the current ceases. An increase in the applied voltage will break down this film and allow more current to flow.

For use as a detector, the battery voltage is adjusted to a value just below the breakdown point of the film. If a radio-frequency signal is then added to the battery voltage, the positive half-waves of the signal will break down the film and allow a small current to flow, while the negative half-waves will not be able to overcome the polarization and will, therefore, produce no effect.

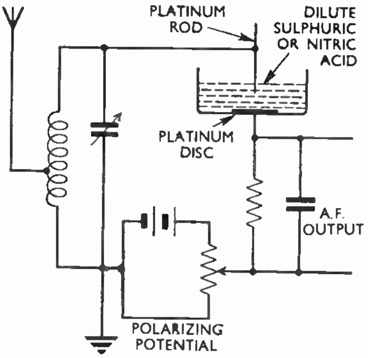


Fig. 18. Circuit arrangement illustrating the principles of operation of the electrolytic detector.

ELECTROLYTIC RECTIFIER. Rectifier in which the asymmetrical conduction is due to the chemical action taking place between an electrolyte and an electrode or electrodes immersed therein.

In one form of electrolytic rectifier, shown in Fig. 19, the electrodes are made of aluminium and lead and the electrolyte is a solution of aluminium phosphate. The electrolytic rectifier has a limited power efficiency and is little used in practice, though it has been used for detection of spark signals. See RECTIFICATION.

ELECTROMAGNET. Core, usually of ferro-magnetic material, which serves as a magnet only so long as an electric current flows through a coil surrounding the core; as distinct from a permanent magnet, which, having been magnetized, retains a large part of the magnetism. An electromagnet provides a means of converting electrical force or energy into mechanical force or work. For this reason, electromagnets form an essential part of many and diverse kinds of electrical apparatus, including meters, vibrators, motors, and loudspeakers. The term is particularly associated with electromagnetic relays. See ELECTROMAGNETISM, ELECTROMAGNETIC RELAY.

ELECTROMAGNETIC COMPONENT. Component of the field existing around a radiating aerial which is at right angles to the conductor, and which represents the radiated energy. The other important component is electrostatic, or electric. See ELECTRIC COMPONENT.

ELECTROMAGNETIC DEFLECTION. In a cathode-ray tube, the deflection of the electron beam by the magnetic field set up by current-carrying coils placed in close proximity to the tube but external to it.

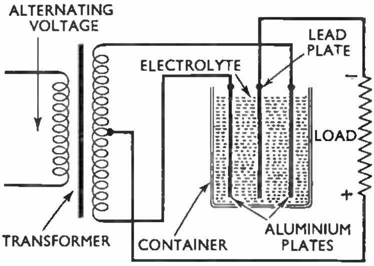


Fig. 19. Electrolytic rectifier connected for full-wave rectification so that a unidirectional current flows in the load.

ELECTROMAGNETIC INDUCTION. Phenomenon which causes an e.m.f. to be set up in any conductor which is crossed by a moving magnetic field or by one changing in magnitude. This can be demonstrated with a winding of a few hundred turns of wire on a cardboard tube, a bar magnet, and a sensitive galvanometer (Fig. 20). If the winding is connected to the galvanometer, the instrument will give a momentary deflection when the magnet is thrust inside the tube, and another in the opposite direction when it is withdrawn. If the magnet is kept in regular to-and-fro movement, the instrument will reveal a corresponding regular succession of currents.

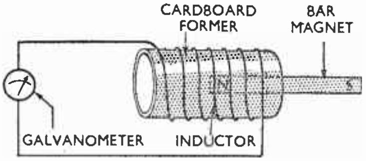


Fig. 20. Electromagnetic inductor formed by several turns of a conductor round a cardboard-tube former; the needle of the galvanometer will "kick," thus registering a momentary current, each time the magnet is moved into or is withdrawn from the tube former.

If the bar magnet is replaced by a second winding on a small tube, and this second inductor is energized with a direct current, exactly the same result will be produced. Further, if an alternating current is used instead of a direct one, there will be no need to move the small tube in and out of the bigger one; the continuous rise and fall of the alternating current in the second winding will cause its magnetic field to cut across the first one all the time. An alternating e.m.f. will, in fact, be induced in the secondary winding. This is the principle of the transformer. See ELECTROMAGNETISM.

ELECTROMAGNETIC LOUDSPEAKER. See MOVING-IRON LOUDSPEAKER.

ELECTROMAGNETIC MICROPHONE. See MOVING-IRON MICROPHONE.

ELECTROMAGNETIC PICK-UP See GRAMOPHONE PICK-UP.

ELECTROMAGNETIC RELAY. Switch operated by an electromagnet. Those used in telephone and telegraph equipment are typical. Relays used in telephone practice may be fitted with several contact units. By their aid, the current in one circuit can be made to control a number of other circuits simultaneously. Because of this feature, they are extensively used in telephone-exchange circuits and also for remote-control purposes generally.

The British Post Office 3,000-type relay (Fig. 21) is typical. It is non-polarized, that is, the operation is independent of the direction of flow of current through the energizing winding.

A core, on which is wound a coil, carries a pole-piece at one end and is attached to a yoke at the other. An armature is pivoted on the yoke close to the pole-piece but spaced from it by a small air-gap. The pole-piece, core, yoke and armature constitute the magnetic circuit. All are made of soft iron having a low value of residual magnetism.

When a current flows through the winding, the armature is attracted towards the pole-piece, but is prevented from striking it by a "residual"

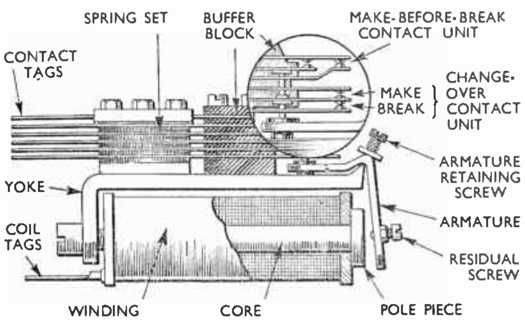


Fig. 21. Details of the 3,000-type electromagnetic relay; it is non-polarized and is a typical example of the relays employed in telephone-exchange circuits.

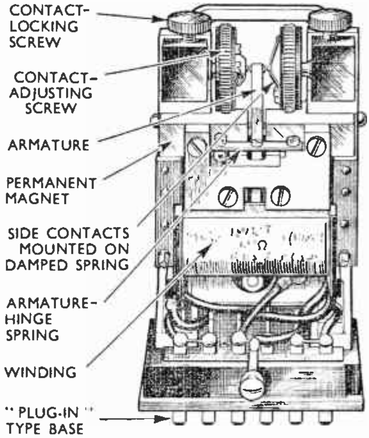


Fig. 22. Carpenter polarized type of electromagnetic relay (as produced by the Telephone Manufacturing Co., Ltd.) for use in telegraphic systems.

stud or screw of non-magnetic material. The purpose of this small residual air-gap is to reduce any tendency for residual magnetism to hold the armature to the pole-piece when the current in the coil ceases to flow. The armature, by means of an extension piece acting as a lever, deflects the movable contact springs of the contact units.

The contact units are of four kinds: "make," "break," "change-over" (break-before-make), and "make-before-break." The last two of these are illustrated in the positions occupied when no current is flowing in the winding, a convention which is adopted when making circuit diagrams.

An assembly of contact units is called a "spring set." Two spring sets are mounted on the yoke. Each contact unit has one movable contact spring and either one or two "fixed" springs. The movable spring nearest the yoke has a lifting pin resting on the armature lever, and another supporting the next movable spring and so on throughout the spring set. Insulating discs on the armature lever and on alternate movable springs and clearance holes in the "fixed" springs prevent short-circuiting.

The fixed contact springs have side lugs which rest against a locating support called a "buffer block" with a force sufficient to ensure a contact pressure of about 20 g. In operation, the movable springs lift the fixed springs from the buffer block and, during the movement, the contact points slide one upon the other so that the surfaces rub sufficiently to ensure a good electrical contact. The contact points themselves are dome-headed rivets made of precious metal to minimize wear by arcing. The metal is generally silver, but for heavy duty platinum may be used. Each contact spring is divided at the free end to form two fingers, and each finger carries a contact point. Such "twinning" of contacts minimizes faults caused by dust.

It is sometimes required, in circuit design, that one contact unit should operate before (X-operation) or after (Y-operation) the other units in a set. X-operation is achieved by shortening the lifting pin of the contact unit nearest to the yoke, and Y-operation by shortening the lifting pin of the contact unit farthest from the yoke. Relays incorporating either of these features are called two-step relays.

The number and kind of contact units determine the mechanical load on the armature lever and, in consequence, the value of the magnetic flux (and the current) required to operate the relay. The operating time is the time required for the flux to build up to the operating value. This is indirectly proportional to the time constant (inductance divided by resistance) of the operating circuit and to the applied voltage.

The releasing time is the time required for the flux to fall to the releasing value. The releasing time depends upon the margin between the working and releasing values of the flux and also on eddy currents induced in the various component parts.

Both operating and releasing times of a general-purpose relay are of the order of 20 millisec. Both can be prolonged by magnetically coupling a circuit having a large time constant. This usually takes the form of a thick-walled copper cylinder (or "slug") threaded on to the core to occupy part of the winding space. It acts as a single short-circuited turn of very low resistance. The effect on the operating time is a maximum when the slug is fitted at the armature end of the core.

The releasing time can be reduced and, to a much lesser extent, the operating time increased, by increasing the residual gap. The holding current and, to a lesser extent, the operating current are both increased by this last adjustment. Operating and releasing times and currents are of great importance in the design of automatic telephone-exchange circuits and in most relay applications.

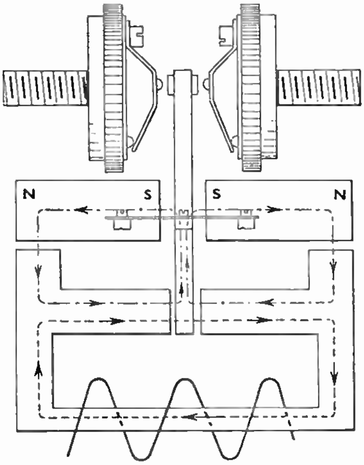


Fig. 23. Diagram showing the magnetic circuit of the Carpenter telegraphic relay which is illustrated in Fig. 22.

The construction of telegraph relays is very different from that of telephone relays. They are polarized, more sensitive, more rapid in operation and made with greater precision. Their prime purpose is to respond to feeble telegraph signals (that is, current pulses of variable duration) and to operate a contact unit so that, in a suitable circuit, it may reproduce the signals with a minimum of time distortion.

A typical relay is shown in Fig. 22, and the magnetic circuit and contact unit in Fig. 23. The magnetic circuit is symmetrical and includes two permanent magnets, the other parts being made of soft iron. When there is no current flowing in the operating winding, the magnetic fluxes on each side of the armature are equal and opposite, and the armature tends to remain in the central (neutral) position shown. In practice, this is an unstable equilibrium and the armature normally rests against one or other of the two fixed contacts.

Passage of current through the operating winding augments the flux through the centre limb on one side of the foot of the armature, and opposes that on the other. The foot of the armature is attracted towards the side carrying the most flux and the remote extremity carrying the contacts moves to the opposite side. The contact gap is made very small, of the order of 0·001 in. By so limiting the movement of the armature from the central position of equilibrium, the sensitivity is increased and the transit time reduced to less than 1 millisec.

Biasing the relay, that is, making the operating current for one direction of movement greater than the other, may be effected by displacement of the "fixed" contacts; upsetting magnetic equilibrium with the aid of a magnetic shunt across one of the air-gaps; or by passing current through an auxiliary biasing winding.

ELECTROMAGNETIC RETROACTION. Synonym for INDUCTIVE FEEDBACK.

ELECTROMAGNETIC SCREEN. Earthed, solid, screen of conducting and, possibly, magnetically permeable material, used to reduce or prevent the spread of electric and magnetic fields into a particular region. See SCREENING.

ELECTROMAGNETIC SYSTEM OF UNITS. System based on the use of electromagnetic phenomena as an integral part of the unit definitions. An example is the absolute ampere. See AMPERE.

ELECTROMAGNETIC-WAVE PROPAGATION. Radiation of electromagnetic waves from a sending aerial to a distant receiving point. See RADIATION.

ELECTROMAGNETIC WAVES. Space fields in which electric and magnetic fields at right-angles to each other travel in a direction at right-angles to both. See POLARIZATION, RADIATION.

ELECTROMAGNETISM. Magnetism produced by the flow of an electric current. Any movement of electrons produces a magnetic field, but the field around a straight conductor is comparatively weak. Strong fields are produced only if the conductor is coiled up into the form of an inductor, when the lines of magnetic force from one turn of wire join up with those of the next turn (and so on through the winding) to produce a total result which is in proportion to the ampere-turns of the inductor; that is, the product of the current and the number of turns.

A current of 1 amp. passing through an inductor of 100 turns produces the same intensity of magnetic field as one of 2 amp. in a winding of 50 turns, and so on; always assuming that the two inductors are of the same characteristics in other respects.

If a long tube of small diameter is wound with a suitable number of turns of wire and a direct current is passed through the winding, the device is equivalent in its magnetic effects to a bar magnet. Its magnetic polarity depends on the direction in which the current passes round the tube, and can be determined by hanging the tube up on a thread, and making flexible connexions to its winding with fine wires attached at the centre. The tube will then, if the suspension is sufficiently delicate, behave like a compass needle and come to rest with its axis in a north-south direction. It may be shown that, with respect to the end which is turned to the north, the electron flow is clockwise round the winding (Fig. 24). There is a simple method for finding the polarity of an electromagnet: place the palm of the left hand on the surface of the winding with the fingers pointing in the direction of the electron flow (from negative to positive of the current source), and the outstretched thumb will then point to the north pole of the magnetic system.

The simple inductor carrying direct current is the electromagnet in its elementary form. For practical purposes, the air-core form is not often used; some material of higher magnetic permeability than air is inserted in the centre of the winding, and a magnetic field many times as strong is obtained (see PERMEABILITY). The material commonly used for this purpose was soft iron, but in modern practice various special ferrous alloys are generally employed because of their still higher permeability.

A special advantage of the iron or alloy core is that, by means of shaped and extended pole-pieces, the magnetic field can be led away from the energizing winding and closely applied to some object such as the armature of a dynamo, so as to concentrate the lines of force just where they are wanted (Fig. 25). The magnetic force follows the high-permeability path as far as the

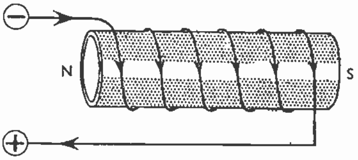


Fig. 24. A fundamental of electromagnetism is the fixed relationship between direction of electron flow in a winding and the resulting magnetic polarity.

iron or other material will carry it, and only emerges into the air when it comes to a gap in the metal.

Electromagnets have innumerable uses in electrical work. In fact, they are used in almost all cases when electrical energy is required to set something in motion. The electric motor uses them in special form; the armature, in many types, consists of a series of electromagnets which are successively energized so that the attraction and repulsion effects between their fields of force and those of the poles of the field magnet set the armature turning to deliver power.

In a particularly wide range of applications, the electromagnet is used to move an object between two possible positions. An instance is the relay (more often called a contactor when it is designed to control large currents). Here the electromagnets attract an iron armature when they are energized; this armature serves to open or close a pair of contacts which make or break the circuit of the current which is to be controlled. In this way, a comparatively small local current, such as can readily be applied through a push-button, can be made to turn on and off a current of such magnitude that it would otherwise have to be handled by a large manually-operated switch (see ELECTROMAGNETIC RELAY).

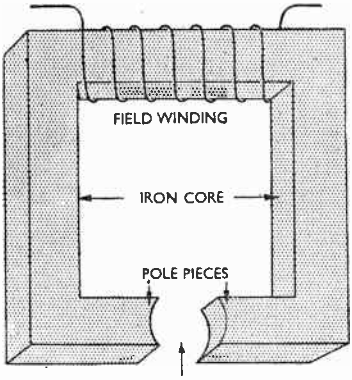


Fig. 25. Simplified diagram of the electromagnetic circuit of a dynamo, showing how the magnetic flux produced in the iron core by the field winding is led by pole-pieces to where it is to act on the revolving armature.

The elements of a contactor-switch are shown diagrammatically in Fig. 26, which illustrates a pair of electromagnets with windings arranged to produce a north pole at one free end and a south pole at the other; an iron yoke joins the iron cores' other ends and so completes the magnetic circuit. The armature is a piece of soft iron on a strip of spring steel. When current is applied to the electromagnets, the armature is pulled down towards them against the resistance of the steel spring. The contact plunger dips then into the mercury cup and completes the circuit that is to be switched on.

When the local current is cut off from the electromagnets, they release the armature, which is lifted again by the spring and withdraws the plunger, which interrupts the main current. (In a practical case, the mechanical arrangements would be more elaborate than the sketch shows, particularly in the provision of adjustable stops to control the travel of the main contacts, and a more effective kind of spring control for the armature.)

The same basic arrangement of an armature moving under the influence of electromagnets is used in two other common devices, the overload release and the no-volt release, or cut-out. In a crude form of the overload release, the strength of the electromagnetic pull on the armature is so adjusted that, under normal working conditions, the armature does not move. But if the load in the circuit rises above a selected value, the current through the electromagnet windings increases so much that the armature is pulled down and causes a pair of contacts to open and so switch off the load.

The no-volt release is simply the charging cut-out found in the electrical

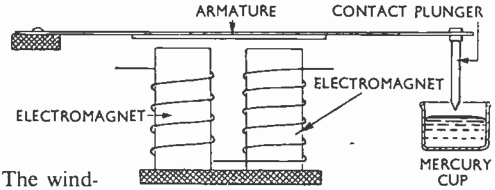


Fig. 26. Contactor-switch operated by electromagnetism, shown in simple diagrammatic form; operation of this unit—a relay—is explained in the text.

system of every motor car. The windings of the electromagnets are connected directly across the output terminals of the charging dynamo, and when the voltage rises sufficiently they pull down the armature. This in turn closes a pair of contacts and connects the dynamo to the battery; charging then begins. When the engine slows again the dynamo voltage falls, the cut-out armature is released, and so the battery is prevented from discharging through the dynamo. There are innumerable applications of the principles of electromagnetism in controlling electrical circuits, but those given serve to illustrate the basic methods.

The electric crane is an example of another interesting range of industrial applications. Although the lifting motive power of the electric crane may, in fact, be steam, the name is explained by the device for grasping the load to be lifted; this is an extremely big and powerful electromagnet, controlled by a switch in the operator's cab. For handling various iron and steel objects the electromagnetic grab has obvious advantages. Another application of the high-power electromagnet is in the magnetic brake used on some electric railways and tramways; in this, the adhesive force between brake shoe and rail is a magnetic one; the shoe is the pole-piece of an electromagnet, and grips the steel rail when energized.

ELECTROMALUX. Tube containing a mosaic which emits electrons when exposed to light as in a television camera. See VISION PICK-UP.

ELECTROMECHANICAL DRIVE. Oscillator used as a carrier source in a sender, and in which the frequency-determining element is a mechanical device such as a tuning fork.

ELECTROMOTIVE FORCE. Driving force which sends an electric current round a circuit. Common instances are the electromagnetic-induction effect of a magnetic field cutting across a winding, or the electrochemical action in a primary or secondary battery. The abbreviation e.m.f. is often used as a synonym for voltage.

ELECTRON. Negatively charged particle of matter; or minute unit of electricity which, in certain circumstances, behaves as though it were possessed of the properties of an exceedingly small and light particle of matter. The electron is part of the complicated structure known as an atom; the number of the electrons and their arrangement play a part in deciding the chemical properties of a particular atom.

Some of the electrons in the atom are attached only loosely, and can move from atom to atom, as when they form an electric current through a conductor. Again, they can emerge from their material source, as when they are ejected by heat from the cathode of a thermionic valve or of a cathode-ray tube.

ELECTRON BEAM. In a cathode-ray tube, or similar device, the narrow stream of electrons emitted through the electron gun and focused on the screen. See CATHODE-RAY TUBE, ELECTRON GUN.

ELECTRON BUNCH. Concentration of moving electrons such as that produced in a Klystron tube. See BUNCHER, CATCHER, KLYSTRON.

ELECTRON CAMERA. Vision pick-up employing electronic scanning, but not the mosaic principle of a storage camera. See IMAGE DISSECTOR.

ELECTRON COUPLING. Coupling between two circuits in which a flow of free electrons is controlled by one circuit, the current carried by the electrons passing through the other circuit. The term could be used to describe a valve amplifier in which coupling between the input (grid) circuit and the output (anode) circuit is provided by the electron stream through a valve.

Since amplifiers have a terminology of their own and because this seldom includes electron coupling, the term is seldom used. It may be used, however, to describe the coupling of an external circuit to an oscillator. The oscillator may be a tetrode with the output taken from the screen grid. The advantage of electron coupling is that changes in the external circuit cause only small changes in the frequency of oscillation. See AMPLIFIER, COUPLING, OSCILLATOR.

ELECTRON DISCHARGE. Passage of electrons through an evacuated space; in other words, it is the electrode current.

ELECTRON DISCHARGE VALVE (OR TUBE). See GLOW-TUBE.

ELECTRO-NEGATIVE. Synonym for NEGATIVE.

ELECTRON GUN. Arrangement of electrodes in a cathode-ray tube which produces an ELECTRON BEAM (q.v.). An ELECTRON JET (q.v.) is emitted by a cathode electrode, passes through an aperture in an electrode and is formed into a beam by one or more focusing electrodes. See FOCUSING ELECTRODE.

ELECTRONIC OSCILLATIONS. In a valve, the very high-frequency oscillations of electrons as they pass between cathode and anode.

ELECTRONIC RECTIFIER. Synonym for VALVE RECTIFIER.

ELECTRONICS. Any technology concerned with the movements of free electrons in a virtual vacuum, or with ion and electron movement in a gas.

The basic tools in electronic technology are hard-vacuum valves and gas-filled valves. The technology of the valve, glow-tube, X-ray and cathode-ray tube is complex and widespread; not only is the valve the heart of all modern practice in telecommunications, but it is also extensively used in industry and in pure physics.

Thus the term electronics covers a wider field than communication, although probably the chief use of the valve is to extend our powers of hearing and seeing by the use of the telephone, broadcasting, telegraphy, television and facsimile. See VALVE.

ELECTRONIC VALVE. Synonym for VALVE.

ELECTRON JET. Term applied to a narrow stream of electrons, whether focused or not. See CATHODE-RAY TUBE, ELECTRON GUN.

ELECTRON LENS. Name given to the arrangement for focusing the electron stream in a cathode-ray tube.

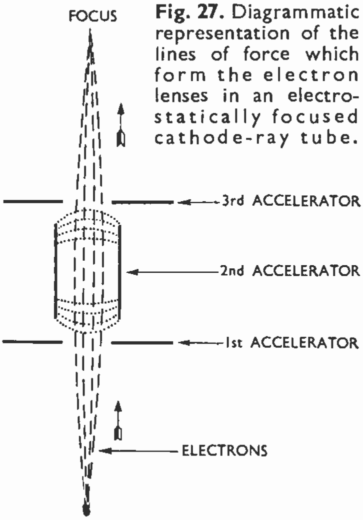


Fig. 27. Diagrammatic representation of the lines of force which form the electron lenses in an electrostatically focused cathode-ray tube.

The electron lens may be either electrostatic or electromagnetic, and is formed by the field created either between the first and second, and second and third accelerators (see ACCELERATOR), or by the field from a focusing coil placed round the neck of the tube.

In the electrostatically focused tube, the focusing field is formed by the electrostatic strain created between adjacent accelerators, the field of force being shaped somewhat as shown in Fig. 27. The effect is to make the electrons bunch towards the centre of the field and so form a narrow beam.

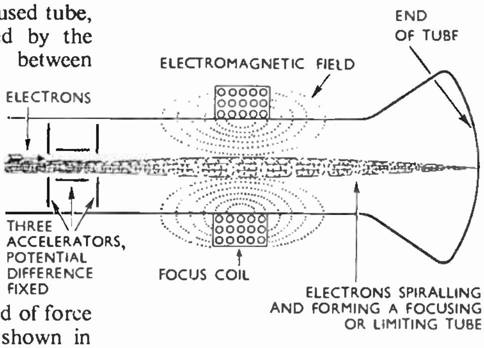


Fig. 28. An electron lens may be in the form of an electromagnetic field produced by a coil surrounding the cathode-ray tube. The diagram shows the "spiralling" effect that this has upon the electrons.

In electromagnetic focusing, the field is so arranged as to be parallel with the path of the electrons. Electrons moving parallel with the field are not deflected, but those that stray from the parallel path tend to be deflected at right angles to the field, and will describe a circular path. Thus, all electrons not travelling parallel with the field will take up a spiral path as they go towards the screen, and by correct adjustment of the field strength can be brought to a focus at the screen (Fig. 28).

In electrostatic focusing control of focus is provided by varying the voltage between the accelerator electrodes, and in electromagnetic focusing by the current passing through the coils forming the lens.

ELECTRON MULTIPLIER. Type of photocell in which high gain is obtained by use of secondary emission. Under the stimulus of light, the photo-sensitive cathode emits electrons which are attracted towards a positively charged anode (Fig. 29). On striking the anode, these primary electrons release secondary electrons which, by suitable choice of anode material, can be made to exceed the primary electrons in number. The secondary electrons are attracted towards a second anode which is more positively charged than the first, and, on striking it, these electrons release an even greater number of secondary electrons. So the process continues to the final anode.

If m secondary electrons are emitted for each primary electron, the stage gain of the electron multiplier is m^n, where n is the number of anodes.

ELECTRON OPTICS. Name given to the use of electromagnetic and electrostatic fields for the purpose of focusing electron streams. It has been found that, in highly evacuated cathode-ray tubes, these fields have a similar effect upon the beam to that of lenses on a beam of light.

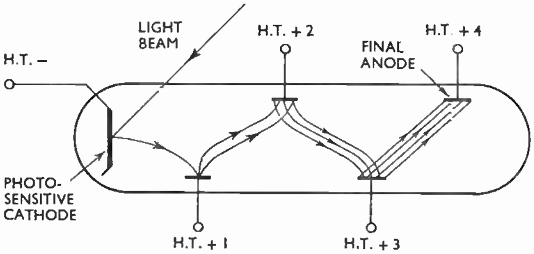


Fig. 29. Principle of the electron multiplier. The H.T. potential applied to the anodes is increased progressively from H.T. + 1 to H.T. + 4. In practice there may be more than the four anodes shown in this simplified diagram.

By means of successive anodes, each being at a potential higher in relation to the cathode than the last anode, the electron stream is not only speeded-up in its path from the cathode, but a curved electrostatic field is caused between the anodes. This, if the tube is properly designed, can be used to bring the electron beam to a focus at a particular point.

The greatest care has to be taken that the dimensions, shape and mutual disposition of the electrodes of a cathode-ray tube are correct if accurate focusing is to be obtained.

Alternatively, magnetic fields created by coils outside the neck of the tube can be used to effect focusing. A great deal of research has been carried out in connexion with the question of focusing, it being especially concerned with the problem of reducing the diameter of the spot caused by the beam on the screen. The smaller the spot, the greater the number of lines that can be used in television and the higher the degree of definition.

Other uses of the cathode-ray tube, notably in radar, also demand the smallest spot possible. So far, by very accurately made anodes, the electron optics of the cathode-ray tube have been successful in reducing the spot to a minimum of about ¼ millimeter in diameter.

ELECTRON RELAY. See GAS-FILLED VALVE, GLOW-TUBE.

ELECTRON STREAM. Synonym for ELECTRON BEAM or ELECTRON JET.

ELECTRON TUBE. Synonym for VACUUM TUBE or VACUUM VALVE.

ELECTRON VELOCITY. Velocity attained by an electron travelling in a vacuum and accelerated by electric or magnetic fields, or by a combination of both. The electrons in an ordinary receiving valve attain velocities of tens of millions of miles per hour; naturally these velocities are possible only when the electron travels in a vacuum or through extremely rarefied gas. An electron urged by an electric field is accelerated just as a body falling from a height is accelerated by gravity; thus it is sometimes said that electrons or ions "fall" through such and such a distance between electrodes, or down a potential gradient.

The graph of Fig. 30 shows electron velocity plotted against voltage. The velocity is that attained by an electron starting from rest, and falling through a potential difference of the amount given on the x axis of the graph. The velocity is plotted as a ratio to the velocity of light (186,000 miles per second, that is, 3×10^{10} cm./sec). It will be noted that increasing the potential gradient does not proportionately raise the electron velocity. This is due to the fact that the effective mass of the electron increases with its velocity; the effect begins to be noticeable at velocities much less than the velocity of light.

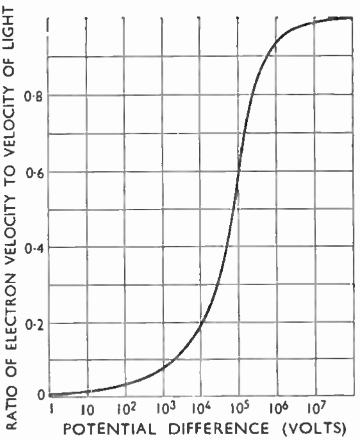


Fig. 30. Graph produced by plotting the difference of potential accelerating electrons (horizontal axis) against the ratio of the electron velocity to the velocity of light.

The values of velocity expressed in miles, feet or centimetres per second are so cumbersome that it is usual to express velocities in terms of a potential difference. Thus we speak of an electron velocity of, for example.

10, 150 or 10,000 volts, rather than in terms of space and time. See ELECTRON VALVE.

ELECTRO-POSITIVE. Synonym for POSITIVE.

ELECTROSTATIC COMPONENT. See ELECTRIC COMPONENT.

ELECTROSTATIC DEFLECTION. In a cathode-ray tube, the deflection of the electron beam, as it passes between two deflector plates, by virtue of the electrostatic charge existing between them.

ELECTROSTATIC ERROR. That component of the total error of a direction-finder which is due to unbalanced capacitance effects, such as unequal capacitance to earth of the two loops of a Bellini-Tosi system. See BELLINI-TOSI DIRECTION-FINDER.

ELECTROSTATIC FIELD. Region in which the forces produced by electric charges act. More particularly, the electrostatic field is that space between opposite charges, or between a charge and an earthed or neutral body. There is, for example, an intense electrostatic field between the plates of a charged capacitor. See CAPACITANCE.

ELECTROSTATIC FOCUSING. In a cathode-ray tube, the focusing of the electron beam into a very small area of the screen by means of the electrostatic fields between two or more electrodes.

ELECTROSTATIC KERR EFFECT. Rotation of the plane of polarization of a light beam in its passage through a transparent medium subjected to an electric strain. This effect is utilized in a number of light-modulation systems, notably the KERR CELL (q.v.). See also KERR EFFECT.

ELECTROSTATIC LOUDSPEAKER. Synonym for CAPACITIVE LOUDSPEAKER.

ELECTROSTATIC MICROPHONE. Synonym for CAPACITIVE MICROPHONE.

ELECTROSTATIC RETROACTION. Synonym for CAPACITIVE FEEDBACK.

ELECTROSTATICS. Science which investigates the properties of electrical charges and voltages. The electric charge, sometimes called static electricity, has been known as a phenomenon from very early times; some of its manifestations, particularly those associated with charges produced by the friction of certain surfaces, are noticeable in everyday life. A simple experiment will demonstrate one of them: tiny scraps of paper are attracted by a vulcanite fountain pen rubbed briskly on a piece of cloth for a few seconds; the vulcanite will pick up the bits of paper in the way a magnet picks up iron filings. This phenomenon occurs because the friction between cloth and vulcanite generates a static charge; if the pen is rubbed by a finger, the effect disappears.

Static charges produced by such methods have been known as "frictional electricity," and much ingenuity has been devoted to devising apparatus to generate it. Some, such as the Wimshurst machine, are capable of producing quite high potentials—up to tens of thousands of volts—and yield sparks of impressive energy. Dry hair and fur when brushed will often yield small sparks—stroking a dry cat in the dark will sometimes produce minute but clearly visible and audible sparks between fur and fingers.

It was early discovered that there appear to be two kinds of electric charge and they are still known as positive and negative, although modern theory teaches that there is, in fact, only one kind of electricity; a charged body is simply one with an excess or deficiency of electrons above or below the normal complement. An excess of electrons means a negative charge, and a deficiency is a positive charge. Simple experiments enable the properties of static electricity to be investigated, and the first rule which is then discovered is that there is a physical force of repulsion between like charges and of attraction between unlike ones.

An instrument known as the gold-

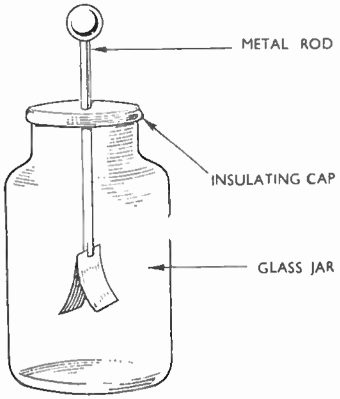


Fig. 31. Gold-leaf electroscope which indicates the presence of an electrostatic charge; when a charge is applied to the rod, the leaves receive a "like" charge and repel each other.

leaf electroscope demonstrates the repulsion between like charges; the essential part of the device is a pair of small slips of gold leaf suspended from the end of a metal rod, so that they hang side by side. The rod is fitted through the insulating cap of a glass bulb (Fig. 31) so that electric charges can be introduced by making connexion with the metal knob on top.

If a negative charge is applied to the rod, it will at once spread itself over the rod and the two thin metal leaves. On each leaf there is now a small charge, and since both charges are negative, they repel each other and the leaves move apart. The main purpose of the electroscope is, of course, merely to detect the presence of electric charges, not to illustrate the principle of repulsion between identical charges.

In the same way that one charge repels another of the same sign, the constituent elements of a particular charge repel each other. Thus if a negative charge is placed on a hollow metal sphere, the individual electrons repel each other and the charge spreads itself uniformly over the outer surface, leaving the interior neutral. Fig. 32 shows how this can be proved with the aid of two electroscopes. One of these is connected to the outer surface of the sphere and shows the presence of a charge by the divergence of the leaves. The other instrument is connected to the inner surface by means of a long wire probe, and the leaves hang down without movement, showing the absence of any charge.

Electrostatic induction is another manifestation of the repulsion of electrons by electrons. If a metal ball is charged negatively and then brought near to a neutral metal ball, the concentration of electrons on the first begins to repel the uniformly distributed normal complement of electrons on the second, and drives them to the farther side of the ball. A negative charge is thus created on the far side of the previously neutral ball, and since there is now a deficiency on the side nearest the first one, the final result is a positive charge there.

If the charged ball is now taken away, the electrons on the second ball distribute themselves uniformly again and the charged condition disappears. If, when the two spheres were close together, a connexion to earth had been made on the far side of the second

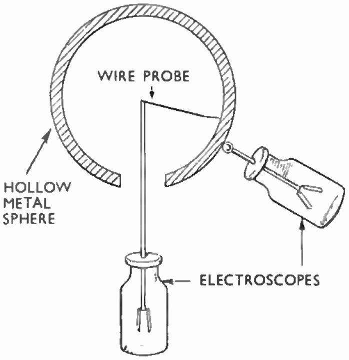


Fig. 32. Experiment in electrostatics which demonstrates that a static charge concentrates itself on the outer surface of an object.

ball, the repelled electrons would have escaped; and on removing the connexion to earth and taking away the first sphere, the second one would be found to have a permanent positive charge, being now short of its normal number of electrons.

Suppose the earth connexion is restored; as the ball is short of electrons, and there is no repelling force in the neighbourhood as at first, electrons flow from earth to bring the potential of the ball back to zero again. Formerly it was said that the positive charge had escaped to earth, but the explanation in terms of electron excess or deficiency gives a much clearer picture of the mechanism of these processes. More information on the implications of these experiments will be found under CAPACITANCE.

Static charges, as such, have little practical application in electrical work; but there are occasions when they must be guarded against as a nuisance or even a danger. For example, one of the ways in which they can be produced is by the evaporation of liquids, and if a steam boiler is operated in conditions which insulate it from earth—on a road locomotive fitted with rubber tyres for instance—it may acquire a charge. If no precautions are taken, anyone touching the vehicle in dry weather while standing on the ground would receive a violent shock. To prevent this, some earthing device, such as a short length of chain trailing on the ground, is provided. See CHARGE OF ELECTRICITY, COULOMB'S LAW, ELECTRIC FIELD, ELECTRIC FORCE, ELECTRON, UNIT CHARGE.

ELECTROSTATIC SCREEN. Synonym for ELECTRIC SCREEN.

ELECTROSTATIC SYSTEM OF UNITS. System based on the use of electrostatic phenomena as an integral part of the unit definitions. More precisely, one which starts by fixing a unit of charge as being that which exerts unit force of attraction on an equal and opposite charge held at unit distance.

ELEMENT. See CIRCUIT-ELEMENT.

ELEMENTAL AREA. Synonym for PICTURE-ELEMENT.

ELEVATED H-TYPE ADCOCK DIRECTION-FINDER. Adcock direction-finder employing vertical half-wave dipoles, with the receiver hut raised to the level of the dipole centres (Fig. 33). The resultant complete symmetry of the aerial-system is helpful in minimizing certain types of error. See POLARIZATION ERROR.

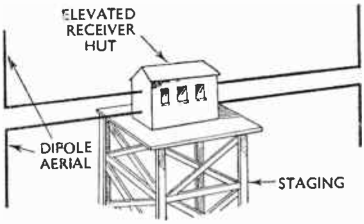


Fig. 33. Elevated H-type Adcock direction-finder. The hut is raised on a staging at such a height that the aerials can be arranged as dipoles; polarization errors on the horizontal lines are thus largely balanced out.

ELIMINATOR. Synonym for BATTERY ELIMINATOR.

ELLIPTICALLY POLARIZED WAVE. Radio-wave whose plane of polarization is rotating and whose amplitude varies according to the direction of polarization. In the process of reflection from the ionosphere, the plane of polarization of the wave is affected. It is usually found that the plane is rotating; thus, at any receiving point, one wave of the electric field may be vertical but the plane of next wave may be slightly rotated, and so on until after a time the wave is horizontally polarized. The process now repeats itself but in the opposite direction. Such a wave is said to be circularly polarized, and the great majority of waves reflected from the ionosphere are of this form.

As well as being circularly polarized, most waves are also elliptically polarized. The actual strength of the wave varies according to the direction of polarization; for example, the field strength may be at a maximum when the wave is horizontally polarized and at a minimum when vertically polarized, thus producing a cyclic variation in amplitude. See CIRCULARLY POLARIZED WAVE, PLANE OF POLARIZATION. POLARIZATION.

e.m.f. Abbreviation for ELECTROMOTIVE FORCE.

EMISSION. Liberation of free electrons from a hot cathode (see also SECONDARY EMISSION). A valve is basically a means of controlling the flow of electrons without introducing any device which has mechanical inertia (see VALVE). Essential to the valve is a supply of electrons to form a conductive path between cathode and other electrodes, the most important of these being the anode.

Conduction of electricity in a conductor is made possible by the existence of free electrons in the conductive substance. Normally, these do not escape the boundaries of the conductor carrying current. But if the conductor is raised to a sufficiently high temperature, the extra energy given to the electrons enables a few to escape; the most convenient way to heat the conductor is by an electric current.

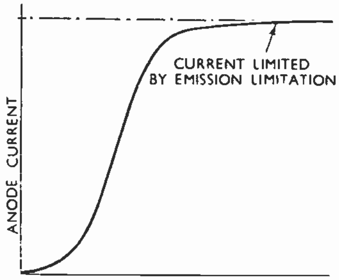


Fig. 34. Anode-volts/anode-current characteristic of a valve, showing the effect of emission limitation. The anode current attains a constant value at a certain anode voltage because the cathode is able to emit only a limited number of electrons.

The electrons, once they leave the conductor, must be free, or they will recombine with positively charged nuclei. If the heated conductor is in a vacuum, the electrons which escape from it form in a cloud around it unless attracted away from the conductor by a positively charged electrode.

Emission is a term associated with the property of a metal or substance which causes it to emit electrons when heated. Some metals give off electrons more easily than others; tungsten is a metal which emits electrons freely, but it has to be raised to a relatively high temperature. Coating tungsten to make thoriated tungsten increases its efficiency as an emitter. Certain oxides are better emitters than tungsten or thoriated tungsten.

Oxide emitters are not always used because the degassing of a valve cannot be so complete when such emitters are used; even if a better vacuum were obtainable, the residual gas would still contain enough positive ions to bombard the oxide and break it up if the anode voltage were large.

Thus pure tungsten, which is the most robust emitter, is used for valves handling from tens to hundreds of kilowatts when the anode voltage is high; thoriated tungsten is used for valves handling hundreds of watts; and oxide-coated cathodes, usually of the indirectly heated type, are used for small valves. See CATHODE, CATHODE EFFICIENCY, EMISSION LIMITATION, FILAMENT, INDIRECTLY HEATED CATHODE, SPACE CHARGE.

EMISSION LIMITATION. Limitation of space current in a valve due to a limitation in the supply of electrons provided by the cathode. Obviously if due to any one of many possible causes the cathode is emitting electrons as fast as it can, then the current flowing from the cathode cannot be increased (Fig. 34).

The limitation may be due to the fact that the temperature of the

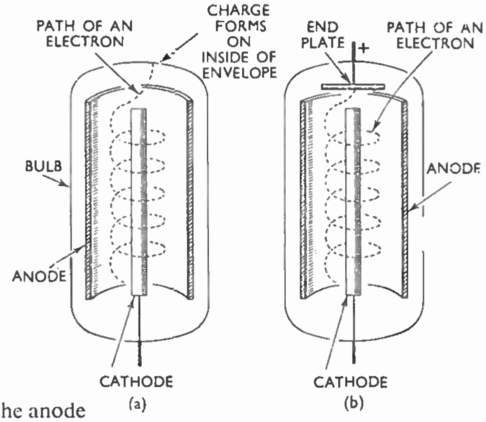


Fig. 35. Diagrams illustrating (*a*) how an electron in a magnetron may trace a helical path and "escape" to strike the inside of the glass envelope, and (*b*) attraction of the electron to a positively charged end plate.

cathode is not high enough because the filament or heater current is not sufficient. If in a diode, for instance, the anode volts are so great as to demand that each electron, immediately it is emitted, shall fly to the anode, no surplus is then available and the anode current cannot be increased beyond a limiting value. See DIODE, GAS-FILLED VALVE, VALVE.

END-FIRE ARRAY. Assembly of aerials so arranged that the direction of maximum radiation, or most efficient reception, is along the line of the array, in distinction from the broadside array. See BROADSIDE ARRAY, YAGI AERIAL.

ENDODYNE. Synonym for AUTO-HETERODYNE.

END PLATE. Electrode structure used in a MAGNETRON (q.v.) to remove electrons which would otherwise collect on the inside of the bulb. Electrons in a magnetron rotate round the cathode. Some may follow a spiral path and escape from the space between anode and cathode (Fig. 35). But for the positively charged end plate, those electrons not eventually drawn to the anode would hit the inside of the glass envelope and cause a negative charge to build up there. The end plate is, therefore, one means of stopping the formation of a charge on the inside of the bulb.

ENERGY. Capacity of a body to do work. Energy is either potential or kinetic, and is measured, as is work, in ergs or in foot-pounds.

ENERGY COMPONENT. Synonym for ACTIVE CURRENT.

ENVELOPE. Synonym for BULB.

ENVELOPE OF MODULATION. Synonym for MODULATION ENVELOPE.

ENVELOPE VELOCITY. Velocity of the whole of the wave front of an electromagnetic wave. In free space, this is the same as the velocity of light, approximately 186,000 miles per second. In media other than free space the velocity is different and is always less than in free space. See WAVE VELOCITY.

EQUALIZER. Quadripole which, for a constant input, gives an output which varies in a predetermined manner over a certain frequency band. An equalizer, as its name implies, is a network which is used to equalize, compensate for, or "flatten" the attenuation-frequency characteristic of another network, such as a transmission line, or to equalize any other source of power having a variable output over a band of frequencies.

The assumed frequency-response graph of any network or of a line and the result of the use of an equalizer, and the necessary response of an equalizer to compensate for the falling characteristic, are shown at Fig. 36.

Fig. 37 shows some very simple equalizers and their frequency-response characteristics. Some of these equalizers are called constant-resistance equalizers, because the impedance at the

Fig. 36 (*right*). Constant-voltage-fed network whose output passes to an equalizer before amplification (*a*), and attenuation-frequency characteristics (*b*). After amplification by 40 db., the output from the amplifier is the same as the input to the network.

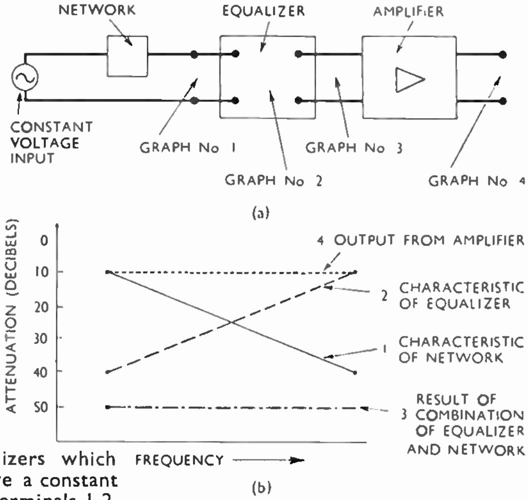
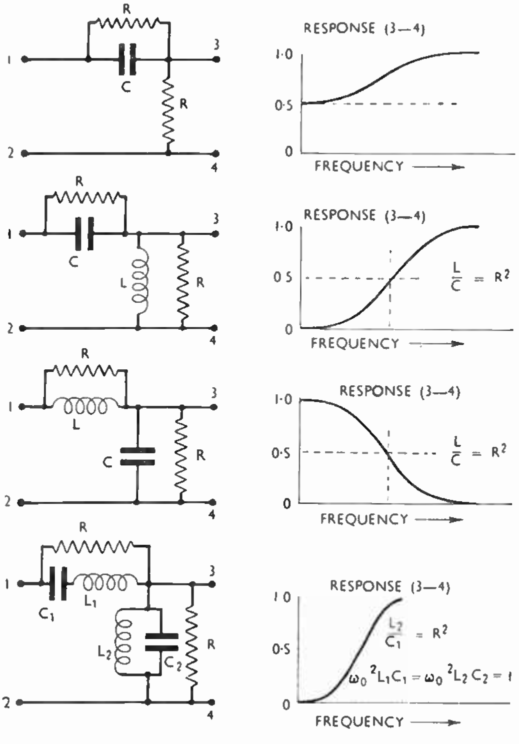


Fig. 37 (*below*). Examples of equalizers with their respective frequency-response graphs, the voltage at the input terminals 1-2 being assumed constant. The three equalizers which show zero response have a constant resistive impedance at terminals 1-2.



input and output terminals may be made constant over a band of frequencies. This is a very useful property when it is desired to equalize a network and terminate it in a resistance. Equalizers are used in line transmission at repeater stations and, at each station on the line, the level is raised and the frequency characteristic is equalized, or "flattened out."

There is some resemblance between an equalizer and a filter because each gives an output which varies with frequency, for a constant-voltage input. The basic difference is that, in the design of a filter, a certain attenuation is wanted at a certain frequency in the attenuation band, and the slope of the attenuation-frequency characteristic at frequencies outside the effective band width does not greatly matter.

In the design of an equalizer, however, the absolute amount of attenuation at any given frequency does not greatly matter, but the shape of the attenuation-frequency characteristic is important because this must be complementary to the shape of the attenuation-frequency curve of the network to be equalized.

The "tone control" in a radio receiver is hardly an equalizer; it more nearly resembles a variable low-pass filter which cuts off the higher frequencies, but the frequency-response characteristic changes less rapidly than in a classic type of filter with reactance elements and resistive termination. The network which compensates for the falling response in a gramophone record between, say, 50 and 250 c/s, is in every sense of the term an equalizer. See FILTER, QUADRIPOLE, TRANSMISSION LINE.

EQUIPOTENTIAL CATHODE. Term describing a characteristic of an indirectly heated cathode. A filament is not an equipotential cathode. From Fig. 38a it is clear that one end of a filament, heated by current from a battery, has a higher positive voltage than the other. The anode-cathode volts therefore differ according to which point of the filament is chosen as a reference. In Fig. 38b, the anode volts are constant if the centre point of the transformer (the electrical centre point of the filament) is considered to be the cathode potential. The potential at the two ends of the filament varies, and it is thus not an equipotential cathode.

When, as in Fig. 38c, the cathode is indirectly heated, the cathode obviously has the same potential along all parts of it and is therefore an equipotential cathode; so is any cathode which has the same potential at all parts of it—the cold cathode of a glow-tube, for example. See CATHODE, FILAMENT, INDIRECTLY HEATED CATHODE.

EQUIPOTENTIAL SURFACE. Any surface on which there are no differences of potential from point to point. It does not follow that such a surface carries no charge, or that there are no potential differences between the surface and its surroundings. For example, a charge on a perfect sphere isolated in space distributes itself uniformly over the surface of the sphere to form an equipotential surface.

EQUI-SIGNAL BEACON. Navigational aid, chiefly for use in aircraft, which enables a pilot to decide whether he is on the intended course; and if not, to which side he has diverged. The beacon lays down a zone of characteristically modulated radiation on each side of the course. These two zones interlock in the central (on-course) zone to produce a third type of sound in the aircraft receiver.

For instance, the beacon might radiate a series of dashes in one

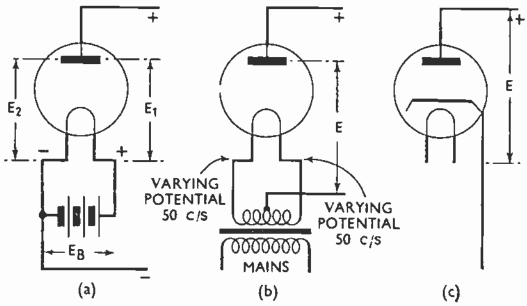


Fig. 38. With the equipotential cathode (*c*) the anode volts are constant; but, in the other arrangements shown, (*a*) the anode volts are less by E_B than E_2, and (*b*) the anode volts E are constant as regards the electrical centre of the transformer, but vary between the two ends of the filament.

marginal zone and dots in the other, while in the central zone, where both signals are heard, the dots and dashes merge into a continuous note. Systems of this type are popularly known as beam-navigation systems.

EQUIVALENT NETWORK. Network which, while different from one it replaces, behaves nevertheless in substantially the same way. The term is one used more in the theory and practice of line transmission than in radio. An artificial line might be called an equivalent network, except that it must slightly alter the performance of the system external to it. The same applies to the artificial or dummy aerial. See ARTIFICIAL LINE, DUMMY AERIAL, NETWORK.

EQUIVALENT SINE WAVE. Sine wave which is equivalent to some non-sinusoidal current or voltage, in that it is of the same frequency and has the same r.m.s. value.

ERG. Unit of work based on the centimetre-gramme-second system of fundamental units. It is the amount of work done when a force of one dyne moves its point of application by one centimetre.

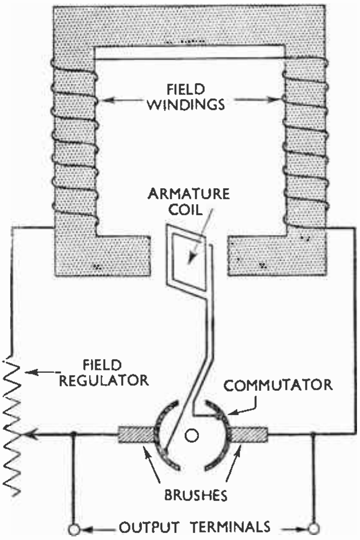


Fig. 39. Excitation circuit which energizes the field magnets in a simple form of shunt-wound dynamo.

ETHER. Non-material medium, assumed to permeate all space, which allows the passage of electromagnetic waves. It is difficult to conceive a wave motion without a tangible medium in which it is passed on from point to point, and so the postulation of an ether came about. The conception of the ether is another way of saying that space, empty of all material substance, still possesses the property of passing electromagnetic waves through it.

When considering the sending of radio waves, empty space is known as "free ether," but when the waves are travelling through material media such as brick houses, the ether is no longer free, but is modified by the presence of the material, and the velocity of the wave is altered while passing through the material.

EUPHON QUILT. Quilt constructed from layers of paper or canvas packed with glass-silk threads. It is used for the absorption of sound waves. See CABOT QUILT.

EUREKA WIRE. Type of wire used for winding resistance coils and heater elements, constructed from a copper and nickel alloy. It can withstand high temperatures without deterioration.

EXCITATION. Current which sets up the magnetic field to perform some electromagnetic operation. Excitation is more strictly defined as the magnetomotive force, but in common usage the current is meant. For instance, the excitation of a D.C. generator or dynamo refers to the current which energizes the field magnets. Fig. 39 shows the circuit arrangement, suitably simplified, of a shunt-wound dynamo; this is the type in which the field winding, which produces the magnetic field through the armature, is connected in parallel (shunt) with the output terminals. The current through any working electromagnet or solenoid is also called the excitation current. See ELECTROMAGNETISM.

EXCITER. Synonym for ACTIVE AERIAL.

EXPANDER. Amplifier or radio receiver which extends the volume range, thus compensating the effects produced by a compressor used in the transmitting chain. See COMPANDER, COMPRESSOR.

EXPONENTIAL HORN. Horn attached to the diaphragm of a loudspeaker or acoustic gramophone, the shape of the horn being such that its cross-sectional area increases progressively in conformity with a logarithmic law. As in Fig. 40, the cross-sectional area may be doubled for each distance of one foot towards its mouth. See ELECTRICAL REPRODUCTION.

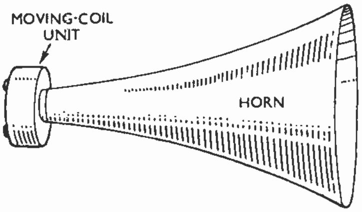


Fig. 40. The cross-sectional area of what is called an exponential horn is doubled for each successive unit increase in length. This design ensures good bass response.

F

F. Abbreviation for FARAD(S).

FACSIMILE. Process of sending and receiving photographs, drawings, and handwritten or printed matter by radio. Modern systems of facsimile are used daily for the sending and reception of photographs between London and America, Australia, India, South Africa, Canada and other countries.

The facsimile machine consists of a cylinder which rotates, at a speed which is controlled by a quartz crystal, and at the same time moves forward along a shaft. On this cylinder is placed the picture to be sent or the photographic film on which a received picture is to be reproduced. The motion of the cylinder is such that a spot of light impinging on the cylinder would trace a helix along it. For sending, a source of light is focused on the picture and the reflected light is directed on to a photocell, the output of which varies in relation to the amount of light picked up from the picture.

Movement of the drum is such that the picture is scanned at about 100 lines per inch and the rotation is set at a speed of between 60 and 90 r.p.m. A quartz crystal controls the motor speed, the crystal being cut for 108 kc/s. A frequency divider reduces this to 10·8 kc/s, which in turn drives a second frequency divider to produce 1,800 c/s. This voltage is used to drive a push-pull motor drive stage and is also applied to a mirror galvanometer for interrupting the light beam on transmission.

The light beam is used to amplitude-modulate an audio-frequency carrier of 1,800 c/s, final modulation being frequency modulation with a deviation of 200 c/s. The deviation to 1,600 c/s represents black, and that to 2,000 c/s represents white, other tone-densities being represented by intermediate frequencies. The frequency-modulated signal, known as the sub-carrier, may be sent over a line or radio channel by normal amplitude modulation, which gives an improved signal-to-noise ratio and greater freedom from distortion. The principal components of facsimile equipment are shown in

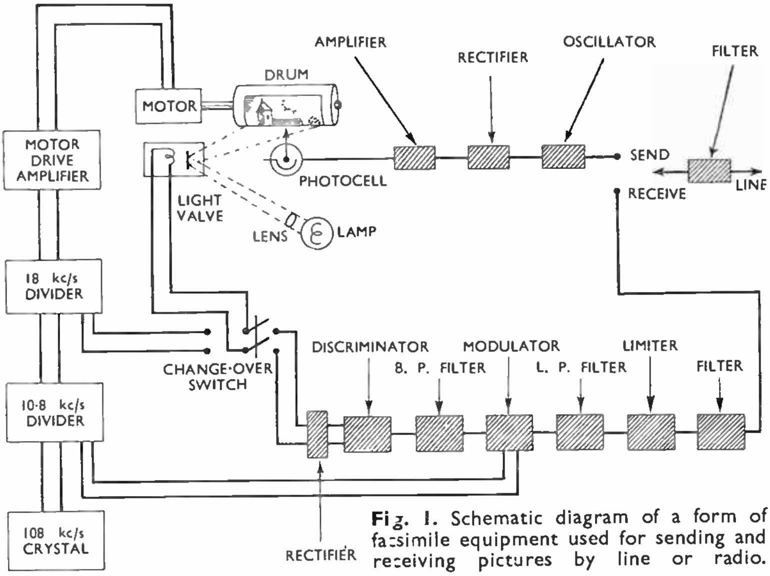


Fig. 1. Schematic diagram of a form of facsimile equipment used for sending and receiving pictures by line or radio.

the above schematic diagram (Fig. 1).

The term "final modulation" has been used in stating that frequency modulation is employed. The amplitude-modulated carrier of 1,800 c/s from the photocell circuits is rectified and the resultant D.C. used to frequency-modulate a beat oscillator which consists of two high-frequency oscillators, the frequency of one being fixed, and that of the other modulated by the picture signal. The frequencies of the two oscillators are usually adjusted so that, with no modulation (no output from the photocell, the picture being black), the beat note is 1,600 c/s. With full modulation (white), the beat is arranged to rise to 2,000 c/s.

On reception, the frequency-modulated sub-carrier is limited to remove all trace of amplitude modulation and is then passed to a frequency-discriminator which reproduces an amplitude-modulated audio-frequency carrier. This signal is rectified and utilized to operate a light valve controlling the amount of light falling on a photographic film carried on the receiver drum which is rotating at the same speed, and in the same phase, as the sending drum.

FACSIMILE TELEGRAPHY. System for transmission of still pictures, printed matter, etc., over an electrical circuit.

FACTOR OF SAFETY. Number specifying the ratio of two quantities, one giving normal working conditions and the other a condition at which breakdown of the apparatus will probably occur. Thus, valves and capacitors are given figures to specify safe working conditions, and manufacturers give test conditions which exceed these figures; but few speak of factor of safety in this connexion and the term is seldom used in radio engineering.

FADE-IN. Term used in broadcasting when sound or vision signals are gradually brought up from zero intensity to that intensity required for the normal working of the system. Fade-in is frequently used to add artistic effect to studio productions.

FADE-OUT. Reverse of FADE-IN. In sound, the signals are gradually brought from normal level to the point of inaudibility; in vision, the picture is reduced from normal brightness to darkness.

FADER. In general, a volume control. In broadcasting, the instrument used for fading-in or fading-out sound or vision signals. It may consist of the gain control of an amplifier, or a completely separate volume control operated at a remote point.

In construction, it may take the form of a continuously variable resistor (when the slider makes physical contact with the resistor element), or a tapped resistor winding, the slider moving over contacts to which the tappings are connected. In the latter case, the tappings are so arranged as to produce small signal changes between adjacent studs. Common values of change are 0·5, 1·0 and 2·0 db. See VOLUME CONTROL.

FADE-UNIT. Fader designed to cross-fade from one programme source to another. It usually consists of two or more faders mounted on a single panel, as illustrated in Fig. 2. The controls may be individually operated or ganged in pairs to give two-channel fade-unit, four-channel fade-unit, etc. The fade-unit is sometimes called a mixer.

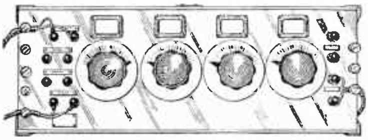


Fig. 2. Four-channel fade-unit, or mixer, as used by the B.B.C.; it contains four constant-impedance faders for connecting four microphones to the input terminals of one amplifier.

FADING. Variation in signal strength at the receiver. There are two different types of fading: that which causes complete disappearance of signals for several hours or even days, and that giving slow or rapid variations in signal strength.

Complete fading is due to magnetic-storm activity caused by solar eruptions and sunspot activity. The ionization intensity of the E- and F-layers is increased to such a degree that complete attenuation of the ionospheric wave occurs, reception being possible only within the range of the ground wave. This type of fading is also known as Dellinger effect.

Slow or rapid variations in signal strength can be caused, first, by interference between the ground wave and the ionospheric wave; second, by changes of wave polarization.

The first type is usually experienced in this country when the reception of medium-frequency continental broadcast stations is attempted at night. It is apparent during the reception of high frequencies at all times, when the signal arriving at the receiving aerial is not a single ray, but may be made up of two or more rays arriving by different paths.

In the case of medium frequencies at night, the signal at the receiver may consist of one or more rays arriving via the ionosphere, and the ground ray. The path distance of the ionospheric ray will naturally be greater than that of the ground ray (Fig. 3), so the rays reaching the receiver may or may not be in phase. If the rays arrive at the receiving aerial in phase with each other, then the field strengths will be additive and at a maximum, but, if they are out of phase, the resultant field strength may be zero.

The resultant signal is thus the vector sum of all the arriving rays, and its value depends upon their relative phases and amplitudes. If the ionosphere were a stable medium, the vector sum would be constant and no fading would occur. Unfortunately, the ionospheric conditions vary from instant to instant, the phase of the ionospheric rays varies likewise, and fading, which may be either rapid or slow, results. At high frequencies, the ground ray is a matter of no importance; it is the changing phase-relationships between ionospheric rays which cause fading.

The second type of fading, due to change of wave polarization, concerns the ionospheric rays only and is therefore most important at high frequencies where reception is normally by means of the ionospheric wave.

Assuming a vertical sending aerial, the radiated wave would normally be vertically polarized, and the signal strength at the receiver, if a vertical receiving aerial were used, would be a maximum. Unfortunately, during the process of reflection in the ionosphere, it is found that the plane of polarization of the wave is usually made to rotate; for instance, it may emerge from the layer vertically polarized at one instant and horizontally polarized a second later. Field strength may also vary with the plane of polarization. The voltage induced in our vertically polarized receiving aerial will therefore vary considerably, and may at times be zero.

It is also possible for the carrier wave to be affected when the sidebands are not, which results in unpleasant distortion. This action is known as selective fading. Thus, in short-wave communication, fading is generally the most difficult feature to combat; but much can be done by the judicious use of special aerial-systems and automatic gain-control. See ABNORMALLY POLARIZED WAVE, AUTOMATIC GAIN-CONTROL, DIVERSITY RECEPTION, IONOSPHERE, MAGNETIC STORM, POLARIZATION, SELECTIVE FADING.

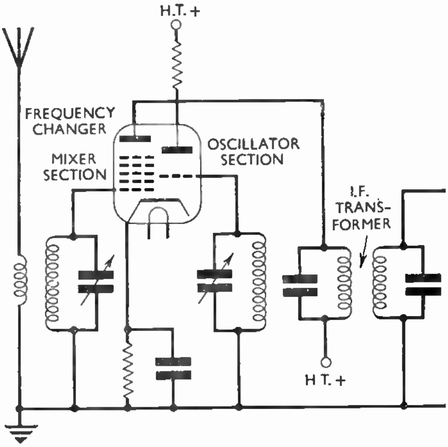


Fig. 4. Fault-finding technique follows a logical step-by-step process; and this diagram of the essential components of a four-valve superheterodyne receiver for A.C.-mains operation illustrates the method of tracing faults described.

FAN AERIAL. Almost obsolete aerial-system composed of wires which radiate upwards from a point at or near ground level to form a flat fan.

FARAD. Unit of capacitance. It denotes that capacitance which, when charged with one coulomb, is raised

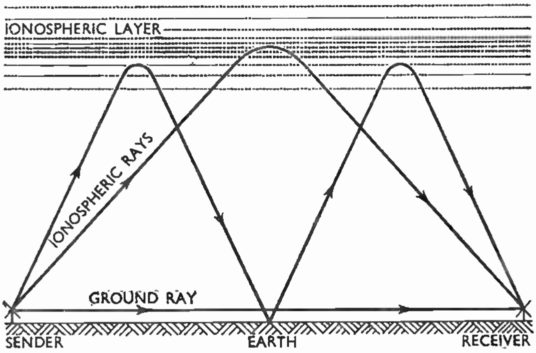
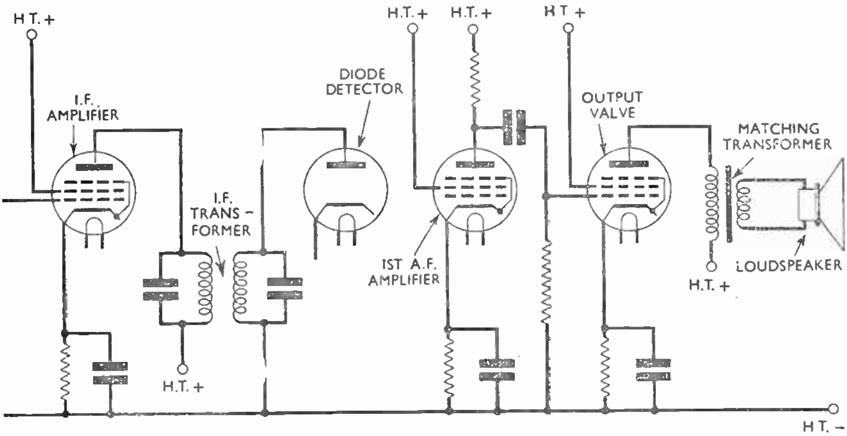
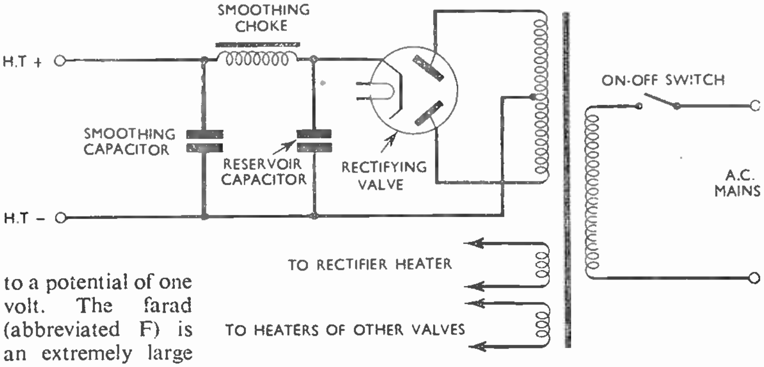


Fig. 3. Rays which combine to form the wave arriving at a radio receiver. Each ray has a final phase-relationship depending upon its path distance, which is continually varying; thus the received signal varies in amplitude.





to a potential of one volt. The farad (abbreviated F) is an extremely large unit, and is therefore commonly used only in a subdivided form such as the microfarad (abbreviated μF).

FARADAY CAGE. See SCREEN.

FARADAY'S LAW. Law named after its enunciator which states that, in the process of electromagnetic induction, the magnitude of the induced voltage depends on the rate of change in the number of magnetic lines of force which link with the conductor in which the voltage appears. The law indicates that in, say, a dynamo the induced voltage is related in a precise manner with the strength of the magnetic field in which the armature turns, with the number of turns of wire on the armature and with the speed at which the armature rotates. See ELECTROMAGNETIC INDUCTION.

FAULT-FINDING. Detection of faults in the component parts or the wiring of equipment. Certain of the faults commonly occurring in electronic equipment have such obvious symptoms that they are detected at once on inspection of the apparatus, whereas others are so subtle that a long and systematic search is sometimes necessary before they are detected. In particular, intermittent faults are frequently very difficult to trace.

If a fault is not obvious, it can sometimes be found by certain tests on particular sections of the equipment, particularly if the apparatus is a very familiar one, but, in general, a systematic process of elimination is the quickest method of fault-finding. To illustrate the methods of fault-finding a conventional four-valve superheterodyne receiver for A.C. mains is here used as an example, and a simplified diagram is given at Fig. 4.

Suppose the receiver is completely silent when connected to the mains and switched on, there being no trace of hum in the loudspeaker. If the valves are not alight, a fault is indicated in the mains lead, in the mains transformer or in the on-off switch, and a continuity test (Fig. 5) applied to each of these in turn should indicate where the fault lies.

If the valves light and the loudspeaker is silent, a measurement should be made of the H.T. supply at the smoothing capacitor. If this is zero, the rectifying or smoothing equipment is clearly at fault, and continuity tests should be made of the H.T. secondary winding of the mains transformer and the smoothing choke. The reservoir and smoothing capacitors should be tested for short circuits and open circuits. If no fault is found, the rectifier valve should be replaced.

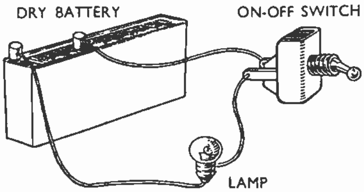


Fig. 5. Simple continuity test, using a lamp and battery, which may be applied to an on-off switch that is suspected of being faulty.

If the H.T. supply at the smoothing capacitor is satisfactory, measurements should be made at the anodes and the screen grids of all the valves. If zero readings are obtained anywhere, an open-circuited anode or screen lead, or a short-circuited decoupling capacitor should be suspected and appropriate tests made (see TESTING).

If correct readings are obtained at all points, all anode currents should be measured. It is not necessary to break any connexions to do this, for the anode currents can be checked by measurements of the p.d. across the automatic bias resistors in the cathode circuits. Such tests also check that the grid-bias values are correct, and that the resistors themselves are of correct value. If any anode currents are found to be markedly different from the normal value, the valve should be tested or replaced by another which is of the same type and known to be satisfactory.

If the fault is still undetected, it is a good plan to inject signals into the amplifying chain at various points to determine in what section of the receiver the fault lies. An audio-frequency oscillator is very useful for this purpose.

First a large output from the oscillator is applied to the primary of the loudspeaker-matching transformer. If no sound is heard from the loudspeaker, the transformer windings and the speech coil should be tested for open and short circuits. If the oscillator output is heard satisfactorily, the output of the oscillator is transferred to the grid of the output valve and the sound should, of course, now be heard at much greater volume.

If the loudspeaker is silent, the output valve may be faulty or the grid leak may be short-circuited. Tests should be carried out on both. If the output valve is functioning correctly, the oscillator output should be transferred to an earlier point in the A.F. chain. If the fault is in the A.F. chain it should be possible, by this method, to determine at what stage it occurs; the components at that point, including the valve, should be subjected to individual tests (Fig. 6).

If the A.F. section of the receiver is working satisfactorily, the fault clearly lies in the I.F. or R.F. sections or in the oscillator. To test the I.F. amplifier, a signal generator is necessary. A modulated R.F. signal of about one volt in amplitude, and at the intermediate frequency of the receiver, is applied to the detector anode and, if the modulation frequency is heard at the loudspeaker, should then, of course, be transferred to the grid of the I.F. amplifier. If signals in the loudspeaker now cease, the fault lies in the I.F. valve or in the I.F. transformer between this valve and the detector, and both these components should be given individual tests for open and short circuits (and mistuning in the case of the I.F. transformer).

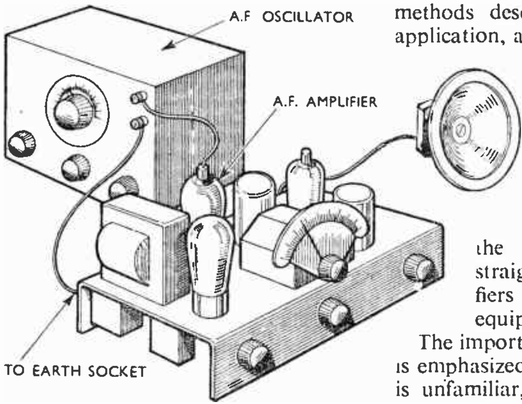


Fig. 6. Method of testing the audio-frequency amplifier of a receiver by means of an A.F. oscillator.

If the I.F. stage is functioning satisfactorily, the modulated test signal is transferred to the grid of the frequency-changer and the frequency of the signal must be adjusted to agree with the tuning of the receiver. If no sound is heard, it is possible that the oscillator section of the frequency-changer is not functioning. This may be checked by noting the reading of a D.C. voltmeter connected between oscillator anode and H.T. negative as the oscillator grid is earthed.

If the oscillator is working correctly the voltmeter reading will alter appreciably when the grid is earthed. If results are satisfactory when the modulated signal is applied to the frequency-changer grid but not when it is transferred to the aerial terminal, the fault lies in the tuned circuits at this point, and simple continuity tests should enable the fault to be traced.

It will be appreciated that the methods described are of universal application, and they may be used for the detection of faults in straight receivers, A.F. amplifiers or any similar electronic equipment.

The importance of a circuit diagram is emphasized; if the faulty apparatus is unfamiliar, every effort should be made to obtain a circuit diagram of it before the location of the fault is undertaken. If no diagram is available the labour is increased enormously. See OSCILLOGRAPH, SERVICING.

FEEDBACK. Condition arising when energy is returned from the output to the input of an amplifier. The energy fed back may be positive, that is, in such a direction as to add to the normal input signal, thus increasing the amplifier output. This is known as *positive feedback*. Alternatively, the energy fed back may be negative, opposing the normal input signal and decreasing the amplifier output. This is known as *negative feedback*.

If positive feedback is permitted to exceed a certain critical value, the amplifier will oscillate. This principle is applied in most oscillators to maintain oscillation, the coupling between output and input being either capacitive or inductive (see CAPACITIVE-FEEDBACK OSCILLATOR, INDUCTIVE-FEEDBACK OSCILLATOR).

A typical example of positive feedback producing oscillation is the howl of a public address system when microphone and loudspeaker are placed too near each other. The output energy from the loudspeaker adds to the normal sound energy applied to the microphone, causing the whole circuit to oscillate at an audio frequency.

Negative feedback reduces harmonic and attenuation distortion, and tends to stabilize an amplifier. It also has the effect of stabilizing oscillators when it is less than the positive feedback necessary to maintain oscillation. See CURRENT FEEDBACK, NEGATIVE FEEDBACK, POSITIVE FEEDBACK, VOLTAGE FEEDBACK.

FEEDBACK AMPLIFIER. Amplifying apparatus or valve in which some major part of the gain comes from the phenomenon of regeneration. For instance, a triode detector provided with a reaction circuit may be described as a feedback amplifier. The term is also used to denote an amplifier with negative feedback. See FEEDBACK, NEGATIVE FEEDBACK, REGENERATION.

FEEDBACK CIRCUIT. That part of a feedback amplifier circuit in which the positive or negative feedback currents flow. For example, in a regenerative detector circuit, such as the Reinartz (Fig. 7), the feedback circuit comprises the variable capacitor which controls the degree of feedback, and the coupling winding which transfers the energy back to the grid circuit of the valve. See FEEDBACK, REGENERATION, REINARTZ CIRCUIT.

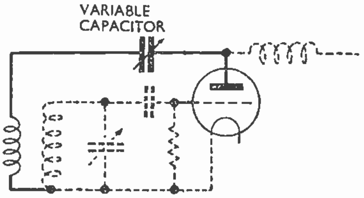


Fig. 7. Feedback circuit, comprising an inductor winding and a variable capacitor (shown in full line), in a detector circuit of the Reinartz type.

FEEDBACK LOOP. Synonym for FEEDBACK CIRCUIT.

FEED CURRENT. See ANODE-FEED CURRENT, ELECTRODE CURRENT.

FEEDER. In general, any connexion between aerial and the sender or receiver; but the term is most often used to denote some form of connexion in which due regard has been paid to its surge impedance in relation to the impedances at either end.

Thus, in the typical case of the necessary connexion between a sender and a distant half-wave dipole, a twin-feeder system (Fig. 8) may very possibly be used, and practical considerations of insulation and weather resistance will probably indicate stout bare wire strung between ceramic insulators, mounted on poles for the ground run, and on wooden cross-members at intervals along the mast or tower for the vertical section. With a reasonable spacing between the pair of wires, a feeder line of this sort will have an impedance of perhaps 300 or 400 ohms, and it must be matched at one end to a dipole whose impedance in the centre is something like 80 ohms, assuming that the feeder is intended to work in travelling-wave fashion (see TRAVELLING-WAVE AERIAL).

The necessary match can be obtained with the aid of a quarter-wave line or "matching stub" close against the aerial, and a similar quarter-wave transformer device between line and sender, although, in many cases, it is just as effective to tap the feeder line across a suitable fraction of the inductor in the output circuit of the sender.

The open-wire, twin-feeder system has numerous advantages for use on the higher frequencies; with usual spacings, it is comparatively non-radiating and, if the pair of wires is arranged side by side, the capacitance to earth from each conductor is equal, so preserving the state of balance which is so often desirable in practice.

With due attention to certain points of design, such a feeder can carry power to considerable distances with only moderate attenuation; feeder runs of half a mile in length are quite practicable.

The points of design requiring particular care are these: first, the spacing of the wires must be accurately maintained at the right figure to give the intended line impedance, this is fixed by the size of the wire and the spacing, and is equal to $276 \log_{10} \frac{d}{r}$, where d is the distance between wire centres and r is the wire radius. It is necessary to take some pains to keep the spacing constant, because variations represent changes of impedance which will set up reflection effects in the radio-frequency currents travelling along the feeder.

Second, a satisfactory set of insulating mountings is essential. Here again impedance discontinuities must be avoided, and this means that the insulators, besides serving their principal purpose with efficiency in both dry and wet weather, must not be designed so that they place masses of dielectric material in the space between the two wires which they are supporting. Stand-off insulators mounted on angle-irons (Fig. 9) are an effective way of meeting this requirement.

In order further to minimize the effects of the insulators it is often considered advisable to adopt a fairly wide spacing, say 6–10 inches, for the pair of wires. Small spacings are sometimes used. but generally only in special cases in which a feeder line of unusually low impedance is desired, perhaps to facilitate matching to a large array of dipoles; or because it will be used for both sending and receiving and it is required that as little energy as possible shall be picked up by the feeders.

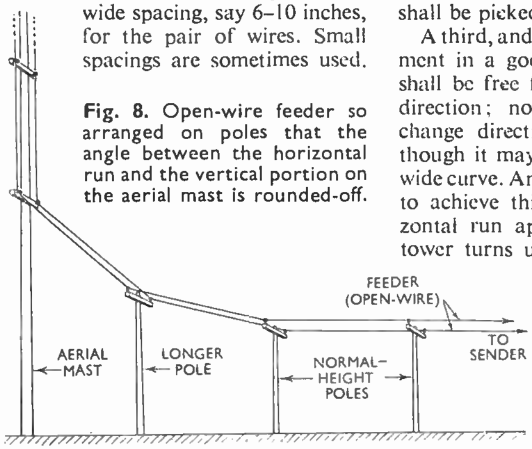


Fig. 8. Open-wire feeder so arranged on poles that the angle between the horizontal run and the vertical portion on the aerial mast is rounded-off.

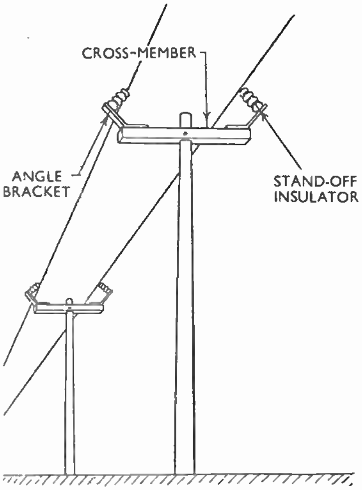


Fig. 9. One method of carrying an open-wire feeder on poles which are fitted with suitable cross-members to support the mounting insulators.

A third, and often neglected, requirement in a good feeder line is that it shall be free from abrupt changes of direction; nowhere should the run change direction in a sudden angle, though it may be brought round in a wide curve. An attempt should be made to achieve this even where the horizontal run approaching the mast or tower turns upward into the vertical section (Fig. 8). Also, when a feeder run of any length is being planned, it is good practice to set the supports at intervals which are *odd* multiples of a quarter-wavelength; this, too, helps to reduce reflection effects and hence standing waves.

These are the major considerations in the arrangement of the twin open-wire feeder. But there is another type, the concentric, wherein the conductor is a single strand of wire enclosed in an earthed metal tube or other form of screening sheath (see CONCENTRIC TUBE FEEDER). A feeder run consisting of a pair of such conductors is far less complicated from one point of view because the distance between the pair is now immaterial, moderate bends are fairly harmless, and the impedance value is fixed by the construction of the material.

On the other hand, the true tubular type demands careful upkeep to prevent the entry of moisture, and much skill in installation, especially in making joints and connexions to the ends—it is otherwise easy to introduce impedance discontinuities at these points. Also, unless large and expensive tubes are employed, the small space between conductor and tube limits severely the amount of power that can be passed through the feeder.

More power can be handled by concentric feeders of a slightly different type. In these, the outer screening sheath is of metallic braiding, and the insulation between this and the central conductor is of some solid dielectric material, or partly of such material and partly of air. In this way, robust cables suitable for use on mobile equipments, on aircraft and so on, have been produced in great variety.

Their obvious convenience has led to wide use in the Services, as they permit properly matched feeders to be installed with a minimum of difficulty, but in actual efficiency they do not compare with a good open-wire system; their attenuation is considerable, and they are therefore used only where the run from sender or receiver to aerial is comparatively short. On permanent installations where conditions allow their use, the open or air-spaced tubular feeder is usually preferred.

For receiving purposes and low-power sending, amateurs often use a feeder consisting of twin lighting flex. The attenuation of such material is somewhat severe on high frequencies, but it has one considerable attraction, its impedance is in the general neighbourhood of 80 ohms. The exact figure naturally depends on the number and size of the strands of wire and the kind and thickness of the insulation, but it is near enough to that of a centre-fed dipole to make a tolerable match without need for any special devices such as stubs.

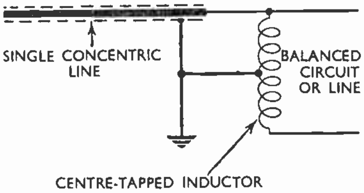


Fig. 10. Method of effecting the change-over from balance to unbalance when, for instance, it is desired to take an unbalanced feeder line to a centre-fed half-wave dipole.

It is sometimes necessary to change from a balanced (two-wire or two-sided) line or circuit to a single-wire unbalanced feeder line. For instance, it may be desired to take an unbalanced feeder to a centre-fed half-wave dipole. The change from balance to unbalance can be effected in the manner shown diagrammatically in Fig. 10. See HALF-WAVE DIPOLE, ZEPPELIN AERIAL.

FERROCART. Proprietary name for ferro-magnetic material having low eddy current and hysteresis losses, which render it suitable for high-frequency uses.

FERRO-MAGNETIC. Property of having a magnetic permeability which is substantially greater than that of air, and which is to some extent a function of the actual flux density. The term is derived from the fact that steel and iron are the typical examples of ferromagnetism. See PERMEABILITY.

FESSENDEN DETECTOR. Another name for the electrolytic detector, which was originally proposed by R. A. Fessenden.

FIDELITY. Degree to which electrically or acoustically reproduced sounds resemble their original counterparts. A high-fidelity system should be capable of reproducing all sounds within the audio range at their correct relative intensities.

FIELD. See ELECTROSTATIC FIELD, MAGNETIC FIELD.

FIELD COIL. Coil of insulated wire used for exciting a field magnet of an electric motor, generator, converter or loudspeaker. Shunt field coils have a large number of turns but carry a small current, while series field coils have few turns and carry a heavy current. See MOTOR.

FIELD-FREQUENCY. Synonym for PICTURE-FREQUENCY.

FIELD STRENGTH. Value of the electric field of a radio-wave at a given point, usually at the receiver site. It is measured in volts per metre (V/m). 1 V/m is equivalent to a potential of one volt induced in an aerial wire one metre long in the direction of the electric field. Since the V/m is too large a unit for practical purposes, the millivolt per metre (mV/m) and microvolt per metre (μV/m) are more frequently used. For example, if 100 microvolts are induced between the ends of an aerial wire one metre long, when a radiated wave cuts across it, the field strength is 100 μV/m.

A signal with a field strength as high as 100,000 μV/m is obtained at short distances from a high-powered sending station. A simple receiver can give a loud signal with a field strength of 10,000 μV/m. But at lower field-strength values, R.F.-amplification stages are required; a signal of 100 μV/m field strength, for instance, necessitates the use of several such stages and a superheterodyne receiver would give better reception. 1 μV/m is the minimum signal which can be received by the G.P.O. Radio Telephony Service, and the reception of such a signal demands exceptionally sensitive heterodyne sets with a number of R.F. and I.F. stages.

The field strength to be expected within the ground-wave range of a sender at distances up to about 300 miles is given, in μV/m, approximately, by the formula:

$$V = \frac{0{\cdot}377 \times 10^{6} \times h\,I}{\lambda d},$$

where h is the effective height of the sending aerial in metres, I the r.m.s. value of aerial current in amperes, λ the wavelength in kilometres, and d the distance from sender in kilometres.

This formula makes no allowance for absorption effects during propagation; various factors, such as that due to Austin and Cohen, may be used to compensate for these losses. Such a formula can, therefore, give only approximate results which often differ considerably from measured values of field strength.

The distribution of field strength around an aerial system is usually exhibited on maps of the area surrounding the aerial. The field strength is measured at a large number of places in the service area of the sender, and places of equal field strength are linked by lines or contours. The shape of these contours is determined by the polar diagram, that is, the directivity of the aerial system, and by features, such as reflections and absorption, in the local terrain. See ABSORPTION, AUSTIN-COHEN FORMULA, ELECTRIC COMPONENT, POLAR DIAGRAM, RADIATION.

FIELD WINDING. Complete set of field coils used in a motor, generator or converter.

FIGURE-OF-EIGHT RECEPTION. Reception based on a polar diagram in which there are two major directions of maximum efficiency at 180 deg. to each other, and, midway between them, two directions of minimum reception, the polar diagram having a figure-of-eight form. The ordinary loop aerial approximates to these properties, as does a horizontal half-wave dipole. See POLAR DIAGRAM.

FILAMENT. Cathode consisting of a conductor, usually of circular cross-section. A current is passed through the conductor, or filament, to heat it. The filament emits electrons and becomes the primary source of electrons. These electrons are available to conduct a current through the valve of which the filament forms the cathode (see CATHODE, VALVE).

The first valves used filaments made of pure tungsten wire. These filaments had to be heated to a high temperature before they gave a sufficient emission, and as the bulb of a valve in those days was clear, the valve gave a certain amount of light (the French called it *une lampe*).

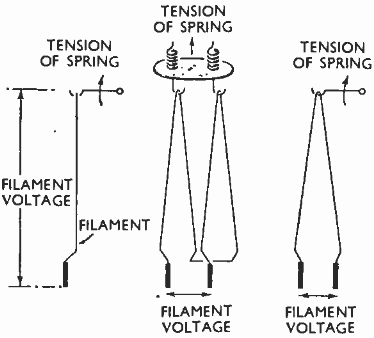


Fig. 11. Various methods of mounting a filament so that its tension is maintained as it expands when heated by the passage of current through it.

Valves with directly heated filaments rated at 1·4 volts or 2·0 volts are in general use in battery receivers. The filaments are coated with a mixture of metallic oxides which give a copious supply of electrons at quite low temperatures. Thus there is practically no glow from these valves and they were originally known as dull-emitters to distinguish them from the bright emitters described.

The valves used in mains-operated receivers are almost always of the type with indirectly heated cathodes. Such cathodes cannot, however, be used in valves handling very high power, such as those required in high-power senders. This is because the bulb cannot be completely evacuated and the small amount of gas present becomes ionized when the anode-cathode potential is applied, and a cathode would be destroyed by bombardment by positive ions which strike it at high velocity under the action of the high anode-cathode voltages used.

Thus a filament is employed in such valves. For powers of up to about 1,000 watts a thoriated-tungsten filament may be used, but for higher powers it is essential to use pure tungsten. Neither tungsten nor thoriated tungsten is such a good emitter as metallic oxides, but other considerations make their use essential (see CATHODE EFFICIENCY).

Fig. 11 shows various forms of filament. The mechanical difficulties introduced by the use of a filament are chiefly those concerned with expansion when the filament gets hot. Arrangements are therefore made to take up the slack by springs. See CATHODE BIAS, EMISSION.

FILAMENT CURRENT. Current flowing in a filament, or the current specified as necessary to produce the required emission from the filament of a specified valve. See FILAMENT, HEATER CURRENT, VALVE CHARACTERISTIC.

FILAMENT EFFICIENCY. Cathode efficiency of a filament-type cathode. See CATHODE EFFICIENCY.

FILAMENT SATURATION. Synonym for EMISSION LIMITATION.

FILAMENT VOLTAGE. Voltage acting across a filament, or the voltage specified as necessary to set up the required filament current of a specified valve. See FILAMENT, HEATER VOLTAGE, VALVE CHARACTERISTIC.

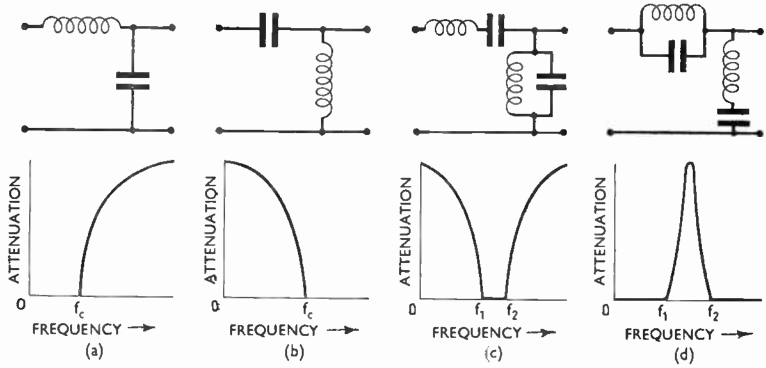


Fig. 12. Filters are classified as (*a*) low-pass, (*b*) high-pass, (*c*) band-pass, and (*d*) band-stop. Below the diagrams of the basic configurations are shown the attenuation-frequency characteristics of each type of filter, assuming it to be ideally terminated; f_c, f_1 and f_2 represent the frequency at cut-off.

FILTER. Network which freely transmits waves within a certain frequency band or bands, and attenuates waves of other frequencies not lying within the transmission bands. Thus a filter is a device which allows waves of certain frequencies to pass freely through it while stopping the passage of others.

Filters are used in every form of transmission technique. Radio receivers must have filters to make them selective (see RESONANCE, SELECTIVITY, TUNING). Similarly, in sending several messages simultaneously over transmission lines, filters are used to pass the band of frequencies representing one message and attenuate all others, so that only the one message is reproduced without confusion.

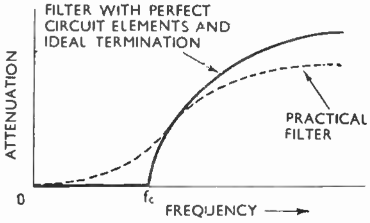


Fig. 13. Diagrammatic representation of the effect of loss (finite Q-factor) in the inductor(s) and capacitor(s) of a low-pass filter; f_c is cut-off frequency.

Filters are characterized in terms of the nature of the bands they pass. A low-pass filter passes waves having a frequency less than a cut-off frequency; a high-pass filter passes waves of frequency greater than a cut-off frequency. A band-pass filter passes waves lying between a lower and an upper cut-off frequency; a band-stop filter attenuates waves lying between a lower and an upper cut-off frequency (see CUT-OFF FREQUENCY).

Fig. 12 illustrates the characteristics of the basic forms of filter: low-pass, high-pass, band-pass and band-stop. The diagram plots attenuation against frequency and shows characteristics applicable to filters built from reactances assumed to have zero loss (power factor = 0, Q-factor = infinity) and to be ideally terminated. There is no such thing as a pure reactance, and the effect of using practical inductors and capacitors in a low-pass filter is shown as a comparison with the ideal graph in Fig. 13. The rounding off of the characteristic about the cut-off frequency occurs in all filters; the low-

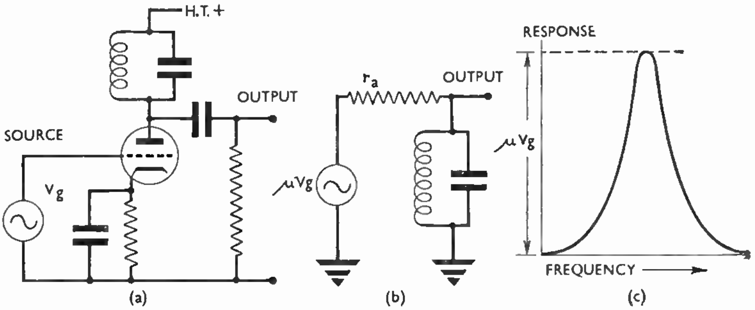


Fig. 14. Valve circuit including a tuned-anode filter (*a*), its electrical counterpart (*b*), and a representative response curve (*c*). The source of e.m.f. is μV_g, where μ is the amplification factor of the valve and V_g the grid/cathode input voltage to the circuit. The resistor marked r_a in the circuit (*b*) is equivalent in value to the slope resistance of the valve in circuit (*a*).

pass filter is chosen only as an example.

Filters are made up from sections containing a series arm and a shunt arm. The circuits in Fig. 12 show what is called the configuration of a filter section; essentially, the series arm of a low-pass filter is an inductor, and the shunt arm a capacitor. Conversely, in a high-pass filter the series arm is a capacitor and the shunt arm an inductor, while tuned circuits form the arms of band-pass and band-stop filters.

A filter is used to transmit waves lying within certain frequency bands so that power can be delivered to some circuit or transducer making use of it. Thus the filter may be inserted between a generator and a load. Ideally, the filter absorbs no power from the source for wave frequencies within the pass or transmission band; the degree to which this ideal is fulfilled is measured by the insertion loss of the filter (see INSERTION LOSS). Over the pass-band, the filter transmits the waves freely; in the attenuation band the filter absorbs no power but prevents power from being delivered to the load. The filter is designed with reference to its cut-off frequency and its termination, symbolized by f_c and R respectively (see FILTER SECTION).

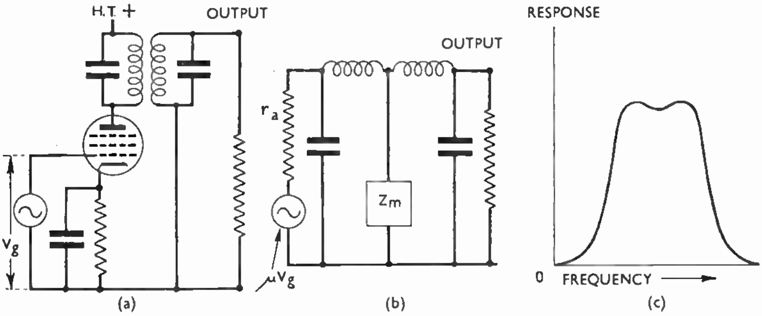


Fig. 15. Inductively coupled band-pass filter (*a*) as used in an I.F. amplifier; its equivalent circuit is a series-and-shunt-arm filter (*b*), impedance Z_m being the mutual inductance between the inductors; (*c*) is a typical response curve.

The foregoing has dealt with what are called Zobel filters, which are used in all transmission technique, notably in connexion with carrier or transmission lines. The radio engineer is likely to find the filter circuit of Fig. 14a more familiar; as shown by its equivalent circuit (Fig. 14b), the series arm is a pure resistance.

In Zobel-filter design it is usual to express the insertion loss and frequency-attenuation characteristics in terms of decibels attenuation, but in radio engineering the response curves are generally plotted in terms of voltage (Fig. 14c). This is because the filters in radio engineering are generally used to feed valve-input circuits

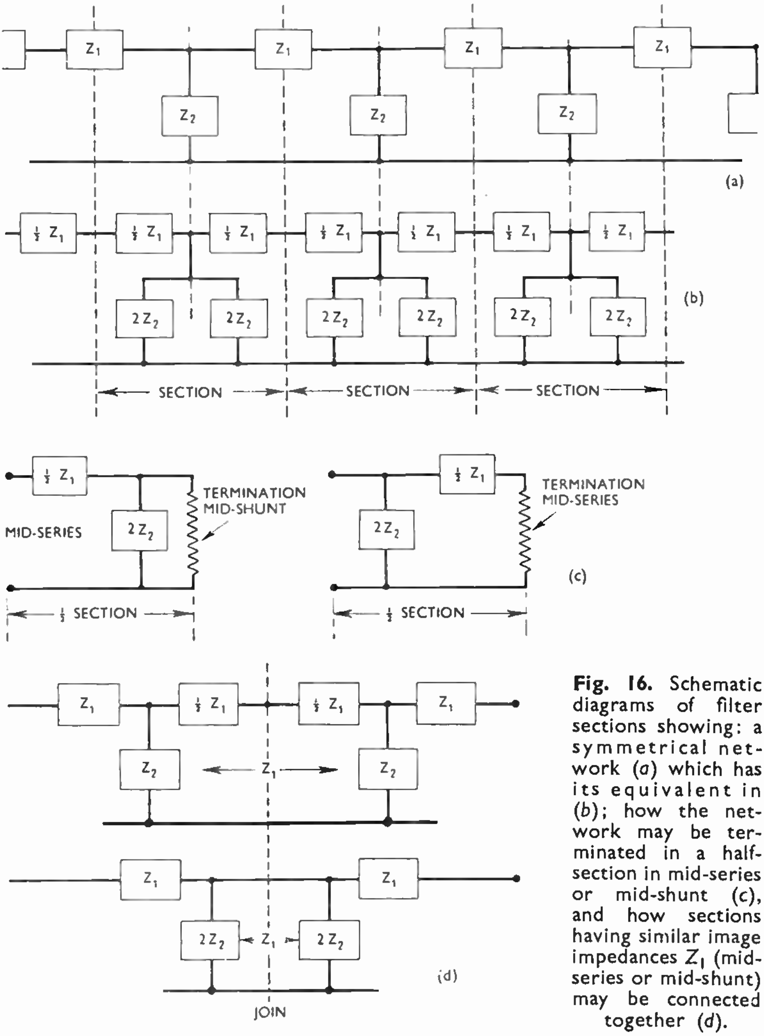


Fig. 16. Schematic diagrams of filter sections showing: a symmetrical network (*a*) which has its equivalent in (*b*); how the network may be terminated in a half-section in mid-series or mid-shunt (*c*), and how sections having similar image impedances Z_1 (mid-series or mid-shunt) may be connected together (*d*).

and valves respond only to the voltage applied to the grid, irrespective of the impedances across which they are developed and irrespective of the power concept implicit in the decibel (see DECIBEL). Fig. 15a shows another circuit familiar to designers of radio receivers, since it is used in the I.F. circuit of a superheterodyne receiver (see BAND-PASS FILTER). This can be likened to a Zobel filter, as a mutual inductance forms the shunt arm (Fig. 15b).

Finally, it should be remembered that an equalizer and a filter each give an output which is a function of frequency, but there is a fundamental difference between them: the filter is designed to give a certain attenuation at a certain frequency, with little reference to the shape of the graph between this frequency and the cut-off frequency, while the equalizer is designed to give a particular shape of attenuation-frequency response, the absolute attenuation being relatively unimportant. See BAND-PASS FILTER, BAND-STOP FILTER, CHARACTERISTIC IMPEDANCE, HIGH-PASS FILTER, ITERATIVE IMPEDANCE, LOW-PASS FILTER, TUNED CIRCUIT.

FILTER SECTION. Network containing, essentially, a series and shunt arm. Sections are designed so that several of them may be connected in cascade with the least possible loss due to mis-matching at the junctions. Fig. 16a shows a symmetrical network in which the series arms have an impedance Z_1 and the shunt arms an impedance Z_2. The network must have an input and an output, but in the diagram (a) this is not shown. In (b), however, it is seen how the network can be considered as made up of series arms containing two impedances in series, each of $\frac{1}{2}Z_1$; and shunt impedances in parallel, of $2Z_2$. Fig. 16c shows how the network can be terminated by its characteristic impedance, in either mid-series or mid-shunt.

Fig. 16d illustrates filter sections considered always in terms of $\frac{1}{2}Z_1$ and $2Z_2$, and how sections can then be connected together without mismatching at the junction.

The constants of filter sections are evaluated in terms of the characteristic impedance R, by which the filter is to be terminated and the cut-off frequency f_c. For example, the constants L and C of an L-type low-pass filter are given by the following expressions: $L = \frac{R}{\pi f_c}$, and $C = \frac{1}{\pi f_c R}$. If only a single section is used, the two capacitors would each be of value $C/2$, and in a multi-section filter the first and last capacitors would also be of value $C/2$. See CHARACTERISTIC IMPEDANCE, FILTER, IMAGE IMPEDANCES, ITERATIVE IMPEDANCE, MATCHING.

FIRST-CLASS BEARING. In direction-finding, a bearing believed to be accurate to within plus or minus two degrees. See SECOND-CLASS BEARING.

FIRST DETECTOR. See FREQUENCY-CHANGER.

FIRST INTERMEDIATE FREQUENCY. First frequency to which incoming signals are converted in a superheterodyne receiver which employs more than one such change. See SUPERHETERODYNE RECEPTION.

FISHBONE AERIAL. Form of end-fire array consisting of a series of elements arranged in end-to-end pairs, each element coupled to one side of a feeder-line through the capacitance provided by an insulator. A diagram

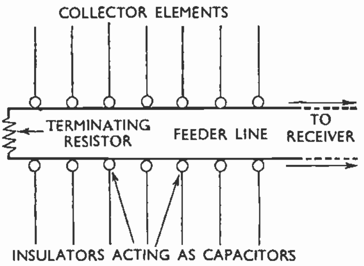
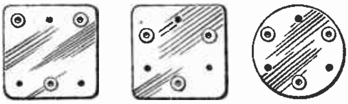


Fig. 17. Elements of the fishbone aerial, showing electrical arrangements but not the supporting devices.



THREE ARRANGEMENTS OF PLATES AND FIXINGS

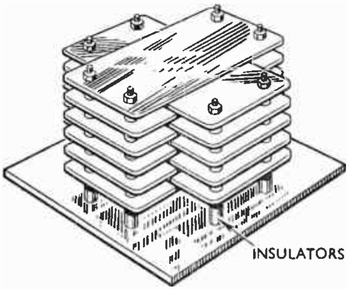


Fig. 18. Typical stacked assembly of conducting plates forming the electrodes of a fixed capacitor with fluid dielectric. The assembly is, of course, housed in a container when the dielectric takes the form of a liquid, vacuum, or gas under pressure.

of the arrangement is given at Fig. 17. Each element is about a third of a wavelength long and the spacing between elements is about a twelfth of a wavelength; there may be as many as 40 pairs of elements. See END-FIRE ARRAY.

FIVE-ELECTRODE VALVE. Synonym for PENTODE.

FIXED CAPACITOR. Capacitor in which no provision is made for varying its capacitance. It is commonly used for coupling and de-coupling A.C. circuits; for by-passing alternating currents; for smoothing rectified power supplies, and as a circuit element in a wave filter.

Fixed capacitors may be classified into several groups according to the dielectric used: vacuum, gas, liquid and solid. The first three have rather a large bulk per unit capacitance, but they have compensating merits which make them particularly suitable for handling the large powers at radio senders. They are being superseded to some extent for this purpose by solid dielectrics. For small transmitters and radio receivers, fixed capacitors having solid dielectrics are almost invariably used.

The first three groups have similar electrode systems, which consist of a stack of conducting plates equally spaced one from the other, and with alternate plates connected to one terminal and the remainder to the other. Typical assemblies are shown in Fig. 18.

Where the supporting rods of one set of plates pass through one of the plates of the other set, the latter is provided with holes large enough to preserve a clearance of the same order as the clearance between adjacent plates. The supporting rods are usually fixed into ceramic insulating plates, or into ceramic insulating bushes fixed to the framework.

Air capacitors designed to work under normal atmospheric conditions can be used in the open form illustrated in Fig. 18, but for vacuum or pressure capacitors, or for capacitors with liquid dielectric, the assembly must,

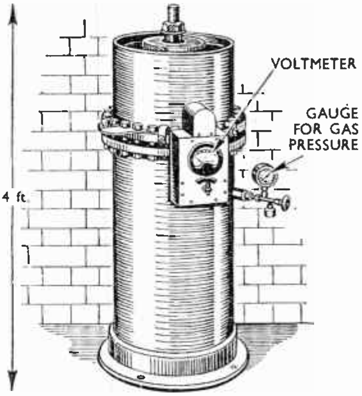


Fig. 19. Pressure container of a Dubilier gas-dielectric variable R.F. capacitor in which nitrogen can be maintained at 200 lb./sq. in. A similar capacitor without the voltmeter and the associated box construction is used, for certain applications, as a fixed capacitor.

of course, be housed in a container.

The container of a vacuum capacitor must be hermetically sealed and strong enough to withstand a collapsing pressure of one atmosphere. For a pressure capacitor, on the other hand the container must be strong enough to withstand a bursting pressure which may be as high as twenty atmospheres. A typical container is shown in Fig. 19.

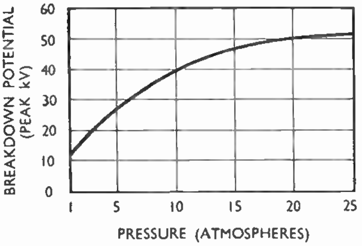


Fig. 20. Graph of the breakdown voltage at 1 Mc/s of a nitrogen-filled pressure capacitor at normal temperature.

To justify these expensive containers there must be some compensation such as a higher working voltage or smaller size, and Fig. 20 shows that breakdown voltage increases with pressure.

A capacitor with a liquid dielectric (for which mineral oil is commonly used) usually has a reservoir mounted above the container, and connected with it, to ensure that the latter is kept full of oil at all times. Any expansion or contraction of the oil with changes of temperature is taken up in the reservoir, which has a small air vent to prevent build-up of pressure. Sometimes a means is provided for circulating the oil to assist cooling and thus to increase the rating.

Compared with air, oil has a higher electric strength and a higher permittivity (about 2·2), but not such a good power-factor. It has the disadvantage that these properties vary with frequency and temperature.

Fluid dielectrics, in contrast with the solid types, have a "self-healing" property; that is to say, the inadvertent application of an excessive voltage for a short time causes no permanent damage. After the excess voltage is removed, the dielectric properties are restored.

The earliest capacitors had glass as the dielectric (see LEYDEN JAR), but its use is now rare. The materials in most common use as solid dielectrics are mica, ceramic and impregnated paper. Plastic films are being introduced and may find a wide application in the future. Electrolytic films, which must be classed as "solid," have a limited scope, but large application.

Capacitors with mica as the dielectric may be divided into foil and metallized types. The former consists of alternate laminations of mica and metal foil (see CAPACITOR), and the stack is held together with metal clamps. In radio types the clamps consist of pressed sheet metal, and the assembly forms the kernel of a synthetic-resin moulding with extending wires or terminal lugs for making the electrical connexions (Fig. 21). For precision purposes the clamps are made of steel plates bolted together, and the assembly is housed in a sheet-metal container filled with wax or bitumen.

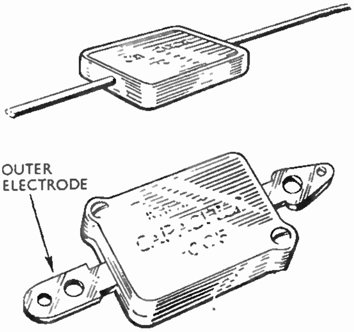


Fig. 21. Two forms of moulding-enclosed mica capacitor, showing provision for electrical connexions.

The electrodes of metallized mica capacitors consist of a film of metal, usually silver, deposited on either side

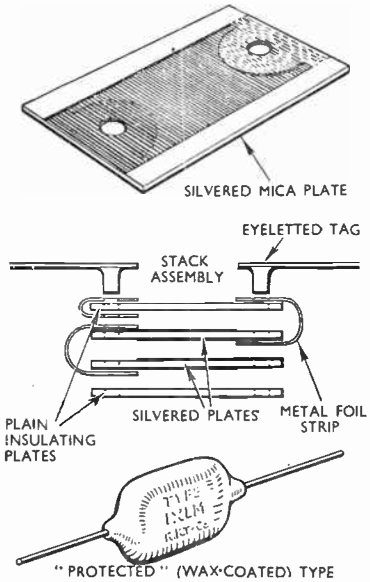


Fig. 22. Constructional details of a silvered mica capacitor, and external appearance of the wax-coated type.

of the mica plate, with clearances at the edges in order to minimize surface leakage and to reduce the possibility of breakdown between the opposite sides (Fig. 22).

To achieve a larger capacitance than that provided by a single plate, several plates may be stacked together and riveted through suitable holes by means of hollow rivets which also serve to attach the terminals. The method of finishing is either to embed them in a synthetic-resin moulding, as for the foil type, or to encase them in wax by a dipping process. The former kind is called moulded, and the latter is termed protected.

Silvered mica capacitors are very stable with respect to time and temperature. They have a very slight instability with change of frequency and voltage, which is of importance only in precision circuits. Its cause has not been fully explained, but it is thought to be associated with isolated particles of silver at the boundary of the metallizing.

Capacitors with ceramic dielectric have, almost invariably, metallized electrodes. The dielectric usually takes the shape of a disc, tube or cup, as shown in Fig. 23. Various grades of ceramic are available for specific purposes. The grade selected for radio senders is usually that having a low power factor. For radio receivers, a high permittivity is preferred so that the physical dimensions may be reduced; a permittivity of 100 or more is available commercially and of over 1,000 in the laboratory.

Several grades are available with large temperature coefficients of capacitance—some positive and some negative—and by judicious mixing during manufacture a wide range of values of the coefficient can be achieved. This is particularly useful for compensating the temperature coefficient of inductance in resonant circuits so that the latter can be made frequency-stable in spite of variations of temperature.

Paper absorbs moisture and is unsuitable as a dielectric unless it is

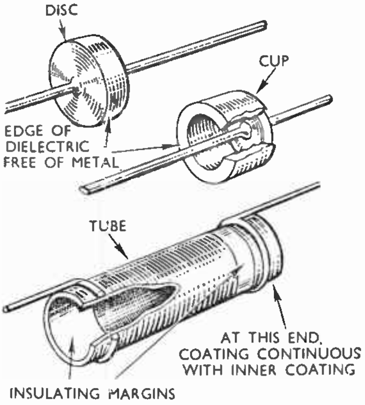


Fig. 23. Fixed capacitors employing a ceramic dielectric usually have metallized electrodes. The dielectric may be a disc, a cup or a tube.

first vacuum-dried and then impregnated with a suitable material. It can be manufactured in continuous lengths of thin and uniform quality (capacitor tissue having a thickness of 7 microns is commonly used) and, together with aluminium or tinfoil 6 or 8 microns thick for the electrodes, may be wound into a roll of large capacitance very cheaply (see CAPACITOR).

The power factor of paper is poor at radio frequencies, but at audio frequencies it is adequate for most purposes. In the range 0·001 to 0·5 μF, and in circuits unsuitable for electrolytic types, paper-dielectric capacitors are extensively used.

Paper is, however, a porous material; also it is impossible to manufacture thin tissue commercially without including a few particles of dust, which may consist of metal, carbon, or other conducting matter. British Standard No. 698 allows a maximum of ten such conducting paths per square foot. This defect may be overcome by superimposing two layers of paper. With this arrangement, the probability of a weak spot in one layer coinciding with one in the other layer is so remote as to be negligible, but the safe working voltage is no better than that of a single layer which is free from defects.

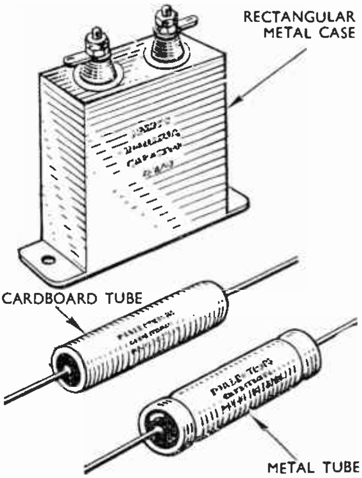


Fig. 24. Three forms of paper-dielectric capacitor. Metal-case types are usually of higher capacitance or higher voltage rating than the tubular ones.

The usual impregnating materials are mineral oil, petroleum jelly, paraffin wax and chlorinated naphthalene wax. The permittivity of the first three is of the order of 2 to 2·5 and of the fourth about 4·5. The permittivity of the cellulose of the paper is about 7 and the effective dielectric constant of the impregnated paper is of the order of 4 and 5·5 respectively, in the two cases. Chlorinated diphenyl has a limited use at power frequencies.

Capacitors having a small value of capacitance are usually tubular in form, but those of larger values are housed in a rectangular metal container as shown in Fig. 24. The construction of the former type is shown under the heading of CAPACITOR. The latter type is wound in a similar way, but on a comparatively large-diameter mandrel. The roll is pressed flat prior to impregnation, and several rolls are connected together in parallel inside a common assembly (Fig. 25).

When a voltage of magnitude sufficient to cause breakdown of the dielectric is applied to a capacitor of the conventional paper-and-foil type, the resulting current through the point of breakdown generates sufficient local heat to carbonize the paper. There is subsequently a permanent short-circuit which is irreparable.

If, instead of a metal foil, the electrode consists of an extremely thin layer of metal deposited on the surface of the paper (metallized paper) then, on rupture of the dielectric, the current is limited to the carrying capacity of the metal layer which fuses in the region of breakdown, where the current is most concentrated. Fusing continues until energy stored in the capacitor falls to a value insufficient to maintain the small arc which is formed. If the stored energy is not excessive and the short-circuit current from external sources is insufficient to maintain the arc, then the heat generated per unit area is so small that the paper dielectric surrounding the point of breakdown is little affected. This "self-healing" property can be used to isolate all the weak spots in a thin tissue, and the reduction in volume, compared with a conventional two-layer design, is 75 per cent.

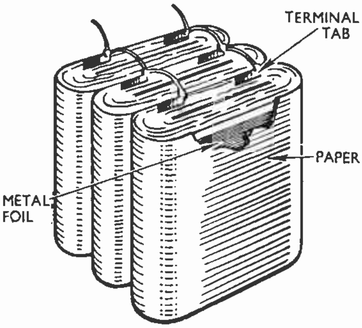


Fig. 25. Details of internal construction of the type of fixed capacitor in which the dielectric is composed of impregnated pressed paper.

The metallized paper usually associated with Mansbridge was invented in 1876 by Fitzgerald, who also described the first rolled type of construction. In 1900, at a time when metal foil was available in lengths of only about 4 ft., Mansbridge developed a commercial method of applying a continuous coating of tin to long paper strips. Prior to this the coating usually lacked continuity, but Mansbridge introduced a calendering process for spreading the separate patches of tin into one another.

With the introduction of thinner tissue, weak spots gave trouble and a method of burning them out prior to winding the metallized tissue into a capacitor roll (in a manner similar to that described above) was introduced. Because of the nature of the coating this technique was not entirely successful, and capacitors using thin tissue were always wound with at least one interleaving tissue, so that there was no intrinsic merit in the method. With the advent of aluminium and tinfoil in continuous lengths, the Mansbridge type of capacitor fell into disuse.

In 1934 Bosch developed a process for applying an extremely thin (0·1 to 1 micron) and uniform continuous coating of zinc to thin tissue by evaporating the metal under vacuum and condensing it on to a passing strip. The tissue was first varnished to fill all the pores and increase the electric strength. The process included a method of coating the edge of the tissue, or other parts required to be free from metal, with a volatile oil which prevented the deposition of the metal.

The technique made it possible to produce commercially, for the first time, capacitors with a dielectric consisting of a single layer of thin tissue. The method has been copied in Great Britain and in the U.S.A. and is finding a growing field of application.

Cellulose nitrate (celluloid) and cellulose acetate were the first plastic films commercially available, but neither they nor pure cellulose have sufficiently good electrical properties to compensate for their high cost in comparison with paper. Nor is it easy to make films thinner than 50 microns with the required degree of uniformity. Cellulose triacetate has been used to a limited extent for capacitors working at 100 deg. C.

Of the newer materials, polythene films are unsuitable mechanically, but polystyrene is most promising and has been used by the Germans as a substitute for mica. Its properties are better than mica in all respects except maximum working temperature, which is 70 deg. C., and temperature coefficient of capacitance. Its insulation resistance is extremely high and its absorption coefficient very low, making it an ideal material for capacitors for use in accurate timing circuits.

An electrolytic capacitor is one in which the dielectric is formed by electro-chemical means on one electrode which, in commercial types, is invariably made of aluminium. In theory, the dielectric can be made of molecular thickness and, in practice, it can be made so thin that, for a given capacitance, size and cost are very much less than of other types. This is particularly true of the capacitors designed for use at the lower working voltages of the commercial range which extends from 12 to 500 volts.

The dielectric is formed under D.C. conditions and, apart from the exceptions mentioned below, electrolytic capacitors are suitable only for polarized working; that is to say, one terminal must always be maintained at a positive potential with respect to the other. Reversal of polarity, even momentarily, causes breakdown of the dielectric, so that the polarized type is unsuitable for use in purely A.C. circuits.

A fluctuating unidirectional potential, however, is tolerable; for example, an A.C. potential superimposed on a D.C. voltage. There are many applications of this kind, such as in smoothing circuits of rectified A.C. supplies, and in decoupling and by-pass circuits. The relative magnitudes of the two must be such that the D.C. component is larger than the peak value of the A.C. component (to prevent reversal of polarity), and their sum must not exceed the rated working voltage. The permissible magnitude of the A.C. components is also limited by the temperature rise produced by the associated power losses acting in a small volume.

Reversible types are made and have a limited use. They consist of two capacitors connected in series, with the polarity of one reversed with respect to the other. The two capacitors are usually constructed as a single unit with one electrode common to both halves. This type can be used in A.C. circuits, but only on very intermittent service because of the large internal power dissipation.

There are two basic types of construction: the "dry" type and the aqueous, or "wet," type. In the dry type, the two electrodes of aluminium foil, one formed and one plain, are separated by a layer of paper impregnated with an electrolyte of a kind suitable for maintaining the chemical film on the electrode. The paper, in this case, is not an insulator but a carrier of the electrolyte, which, in effect, is an extension of the unformed electrode, carrying it into very intimate contact with the dielectric film on the formed electrode. The foils and paper can be wound into a roll in the manner of the paper-and-foil capacitor described earlier.

In the aqueous type the electrodes are spaced apart by insulating supports, and the intervening space is filled with a conducting fluid of the same nature as that used for impregnating the paper in the dry type.

The aqueous type is generally more reliable and less prone to suffer permanent damage as a result of applying a momentary voltage overload; but it is more bulky, and can be operated only in one position. The disadvantages of electrolytic types are their low insulance, high power factor, inconstancy of capacitance, and their ability to withstand only very limited surges of over-voltage. Nevertheless, there are many applications where these disadvantages are not of great consequence and are far outweighed by the considerable saving of size and cost over other types.

Fixed capacitors are marked with the value of capacitance, percentage tolerance and maximum safe D.C. working voltage. This latter figure should never be exceeded, particularly in the case of electrolytic types. Paper-dielectric capacitors are sometimes marked with the test voltage, which is usually about three times the working voltage, except in the case of metallized paper, for which the figure is twice, or even less.

Electrolytic capacitors are also marked with polarity, which it is very important to observe, and sometimes with the peak surge voltage, that is, the permissible voltage that may be applied (without causing damage) for a short period such as occurs when switching on a set. Very small mica and ceramic types, which are too small or inconvenient to mark in any other way, make use of a colour code (see COLOUR CODE).

Because of the internal generation of heat under A.C. working conditions, the maximum safe A.C. working voltage is usually much less than that calculated by assuming that the peak A.C. voltage is the same as the D.C. voltage.

A common fault in capacitors used for coupling the anode of one valve to the control-grid circuit of a following valve is low insulance which causes an excessively high anode current to flow in the second valve. In other applications, low insulance is not usually very important.

Open-circuit and short-circuit faults are serious in any circuit. The first, if suspected, may be proved by putting a known good capacitor in parallel with the suspected faulty one and checking whether the normal performance is restored. A short-circuit usually shows itself by an excessive current but, in cases of doubt, it can be detected by inserting a meter in series to record the current, or a known good capacitor to restore the normal conditions. In all cases, faulty capacitors should be replaced.

Electrolytic capacitors deteriorate with disuse, so that after a shelf life or idle period of six months (or a year at the most) they should be re-formed before use, otherwise they may break down rapidly in service.

Re-forming is effected by applying the working voltage through a current-limiting resistor of about 10,000 ohms for several hours or until the leakage current falls below a value given by the formula $\frac{CV}{5{,}000}$ mA, or 0·1 mA, whichever is the larger, where C is the nominal capacitance in microfarads and V is the working voltage. Thus an 8-μF, 450-V capacitor would be satisfactory if the leakage current did not exceed 0·72 mA.

The capacitance and insulance of electrolytic types fall with time, particularly if subjected to high temperatures, and it is usually necessary to replace them after a few years' service. See CAPACITANCE, DIELECTRIC.

FIXED CONDENSER. See FIXED CAPACITOR.

FIXED DIRECTION-FINDER. Direction-finder in which the aerial-system does not rotate, determination of direction being carried out by other means, for instance, the rotation of a radiogoniometer. See BELLINI-TOSI DIRECTION-FINDER.

FIXED INDUCTOR. An inductor in which no means is provided for varying its inductance. Fixed inductors are commonly used as elements of resonant circuits and wave filters, including simple circuits for discriminating between A.C. and D.C. They are also used for coupling valve circuits. Fixed inductors may be classified according to the nature of their magnetic core, as air-cored, iron-dust-cored, or iron-cored inductors. The choice of core is influenced by the working frequency. Iron cores are used at power and audio frequencies; certain types may be used at frequencies as high as 100 kc/s; iron-dust cores have a useful range from audio to medium-radio frequencies; air cores are used at radio frequencies and also at lower frequencies for special purposes, such as for standards of inductance.

An inductor has some degree of both resistance and capacitance. The conductor with which the coil is wound has intrinsic resistance which is increased by the skin and proximity effects as the working frequency rises. Up to about 1 Mc/s, the skin effect can be reduced in small inductors by employing Litz (stranded) wire. There are other causes of power loss, such as eddy currents induced in nearby conducting material (screens, for example) and, if the inductor has a ferro-magnetic core, eddy current and hysteresis losses in the material of the core.

At radio frequencies, dielectric losses in nearby insulating material, such as the wire-covering and coil former, may become of importance, particularly if the materials contain traces of moisture. There is distributed capacitance between the various parts of the inductor which may be of considerable magnitude in multi-layer coils; the upper value of the useful frequency range is limited to the resonance frequency of the inductance with this stray capacitance. It is the objective of good design to reduce to the lowest practical value all these effects which tend to modify the inductance and Q-factor.

Fig. 26 shows the effective circuit of a fixed inductor, the various losses being represented by series or parallel resistors. At any given frequency, this circuit can be reduced to a simple "effective" inductance in series or parallel with an "effective" resistance. The effective values are not the same in each case, but are related in the manner shown. The parallel values are the more easily measured at R.F. by resonating the inductor with a known parallel-connected capacitor at a known frequency. A.C. bridge methods are used at A.F., and either pair of values may be measured directly.

Fixed inductors for radio senders usually have to carry a current of high value, often at high voltage, and are termed *air-cored inductors*. The physical dimensions tend to be proportional to the power rating. Single-layer air-spaced coils are used which, compared with those used in receivers, have fewer and more widely spaced turns of much larger diameter. The conductor has to be of large section and is usually made of copper tubing. Dielectric losses in insulators must be avoided and coils are supported at as few points as possible by low-loss material. As the working frequency rises, the diameter and the number of turns falls. The power rating also tends to fall with rising frequency so that at V.H.F. the coil is often small enough to be self-supporting.

Receiver inductors have either single-layer coils or multi-layer wave-wound coils wound on cylindrical formers of circular or polygonal section. Single-layer coils are used in resonant circuits at medium and high radio frequencies, and in non-resonant circuits at V.H.F.

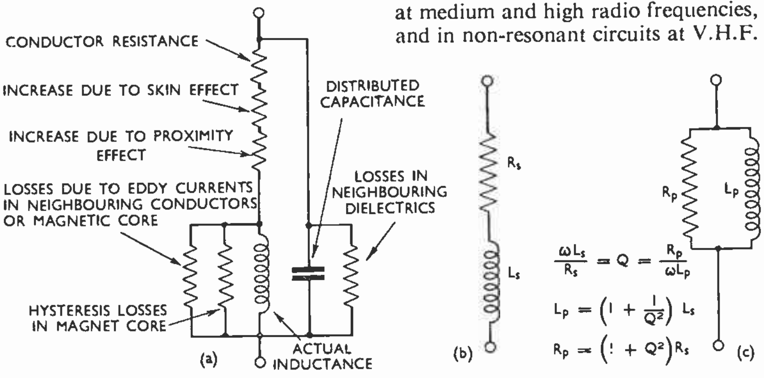
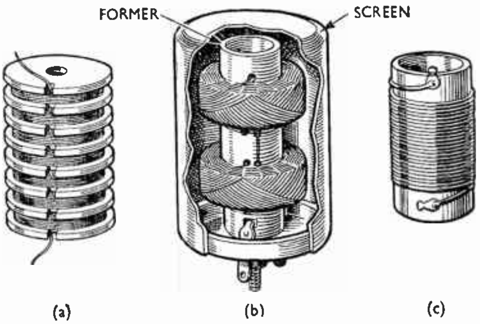


Fig. 26. Diagrams showing: (*a*) losses and capacitance associated with a fixed inductor; (*b*) equivalent series circuit, and (*c*) equivalent parallel circuit.

Fig. 27. Fixed inductors with air cores for radio frequencies: (*a*) a multi-layer winding on a multi-section bobbin; (*b*) two wave-wound coils in series, and (c) a single-layer winding.



Wave-wound coils are used in both resonant and non-resonant circuits at medium and lower frequencies. Multi-layer coils are also used as inductance standards for A.F. measurements. Air-cored inductors are wound with textile-covered copper wire. The Q-factor in the R.F. range is about 150 for types used in broadcast receivers, but higher values can be attained.

A common non-resonant application of fixed inductors is in the anode-feed circuit of a valve. A high value of inductance is necessary to reduce the flow of signal current into the power-supply circuit (whence the terms choke and choke feed). Often the inductor also serves as a coupling element between stages (inductive or choke coupling). The distributed capacitance must be sufficiently low to prevent self-resonance below the working frequency, but designers sometimes deliberately make it coincide with the working frequency in order to increase the impedance. The self-capacitance can be reduced and the resonance frequency increased by sectionalizing the winding, either by having two or more wave-wound coils on a common former, or by using a multi-section bobbin (Fig. 27).

Because of its high permeability, the use of a ferro-magnetic core, in what are known as *iron-cored inductors*, greatly increases the inductance of a coil of given size at zero frequency. As frequency rises, the core introduces an increasing power loss which very soon outweighs the benefit of increased inductance. Losses due to eddy currents induced in the core increase with frequency more rapidly than do hysteresis losses, and are more important. An early attempt to reduce eddy-current losses was made by constructing the core from a bundle of iron wires. The modern method is to build the core from laminations or to use compressed powder (dust cores) and to select material of high resistivity.

Silicon-iron alloys have higher permeability and lower losses than soft iron, and laminations about 0·015 in. thick made from these alloys are used for the cores of power and audio-frequency inductors. Nickel-iron alloys have still higher permeability and lower losses, and are used at audio and carrier frequencies.

The permeability of iron cores tends to change with magnetizing force, and hence with current, through the coil. The permeability first rises with magnetizing force from its initial to a maximum value, after which it falls, at first slowly and then more quickly, until a point is reached where the core is said to be saturated. This non-linear characteristic introduces both harmonic and intermodulation distortion. It is symmetrical about zero, so only odd harmonics are generated.

Another result of this non-linearity is the effect of a direct current upon the incremental permeability and inductance associated with a superimposed alternating current. Most iron-cored inductors are operated in this way, whether in power-supply smoothing circuits or A.F. valve circuits. The introduction of a very small air-gap in the magnetic circuit (Fig. 28) reduces the D.C. magnetization to such an extent that it more than compensates for the increased reluctance, and the incremental permeability and inductance are thus both increased. There is an optimum value of the air-gap beyond which the inductance decreases.

Dust-cored inductors are most frequently used in the wave filters of carrier telephone and telegraph equipment and for loading transmission lines and cables at those frequencies. They are usually toroidal in form (Fig. 29), but in the frequency range where line-carrier and radio systems overlap other shapes may be used. I.F. inductors for broadcast receivers, for example, sometimes have a dust-core in the form of a rod or slug along the axis of a cylindrical coil former. The size of dust-cored inductors tends to be inversely proportional to frequency. The Q-factor is in the range 200–400, but is less at A.F. The windings are usually sectionalized to reduce self-capacitance. See DUST CORE, INDUCTOR, IRON LOSS, LAMINATION, WAVE-WINDING.

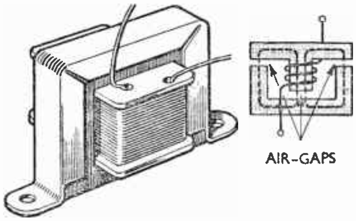


Fig. 28. Fixed inductor which has a laminated iron core assembled with air-gaps in the magnetic circuit.

FIXED RESISTOR. Resistor in which no means is provided of varying the value of its resistance, *R*. Fixed resistors may be put to many uses; they fall, for the most part, into one of the following groups: (1) for controlling or limiting the current, *I*, flowing from a source of e.m.f. *E*, according to the formula $I = E/R$; (2) for producing a potential difference proportional to, and in phase with, the current flowing through it, according to the formula $V = IR$; (3) for reducing the voltage from a source *E* to a value $E - IR$; (4) as an element in a passive network; and (5) for transferring surplus or unwanted energy into heat, according to the formula $W = I^2R$. Some of these applications are illustrated in Fig. 30.

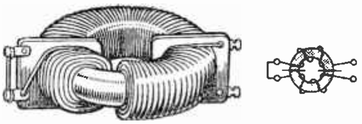


Fig. 29. Fixed inductor, with a toroidal iron-dust core and a two-section winding, widely used in wave filters of telephone and telegraph equipment.

In all applications, some energy is dissipated in the form of heat and the amount determines the design and size. Where the dissipation is less than 3W, metallized or wire-wound types may be used. Above 3W, wire-wound types are used almost exclusively. Metallized types have a very low residual reactance, both inductive and capacitive; they are also cheap and are extensively used in all kinds of electronic circuits. Wire-wound types are very constant in resistance and can be made to much closer tolerance; but they usually have appreciable residual reactance and their use is limited to comparatively low frequencies.

The description "metallized" is commonly used to cover three distinct methods of construction, two of which contain no metal except in the lead-out wires. Strictly, the term describes a design in which the resistive element consists of a thin film of metal deposited on the surface of a ceramic or glass rod. External connexions are made through wires either attached to metal ferrules, or wrapped around the ends of the rod in contact with the conducting film (Fig. 31). The resistance is controlled by varying the thickness of the deposit.

In practice, however, most metallized resistors either make use of a conducting film of carbon instead of metal, or employ a resistive element which consists of a rod moulded from a thermo-setting plastic composition or paste containing powdered carbon or graphite. Except for the high-stability designs described later, the film types are encased in a ceramic tube or a comparatively thick protective wall of moulded plastic and are provided with axial lead-out wires. These are called *insulated* resistors.

The composition types usually have wrapped-around radial lead-out wires. They are protected by a coat of paint (which should not be relied on to provide satisfactory insulation) and are classified as *non-insulated*. Both film and composition designs allow a very wide range of resistance. Film types are made commercially from a few hundreds of ohms to tens of megohms. Composition types are made from tens of ohms to almost the same high value.

The method of construction of the common designs of small carbon resistor does not allow of close resistance tolerance, the normal value of which is ± 20 per cent, but ± 10 and ± 5 per cent can be obtained by selection. To ensure that the number of values of resistance in common use is a minimum and that no carbon resistors are wasted through falling outside the tolerance limits, a system of preferred values has been devised and is generally accepted by industry.

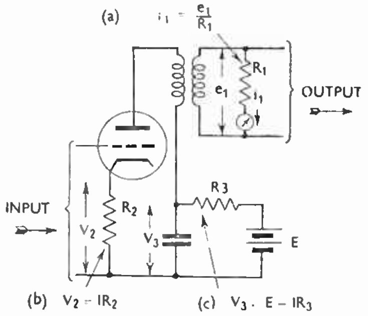


Fig. 30. Circuit diagram showing three applications of fixed resistors; at (*a*), (*b*) and (*c*) are the relevant formulae applicable to this valve circuit.

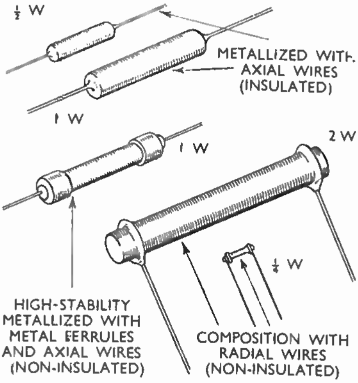


Fig. 31. Forms and relative sizes of the so-called metallized and composition types of fixed resistor.

Tolerances closer than ± 5 per cent are attained by a modification of the film method; a spiral cut is made in the film, having a length which can be adjusted to suit the resistance required. The method has the additional advantage of decreasing the width and increasing the length of the conducting path and, therefore, for a given resistance the thickness of the film may be very greatly increased. This gives improved stability with change of voltage and time, but tends to increase the inductance.

Most of the resistors so far described have the negative temperature coefficient of resistance associated with carbon as the conducting medium; they are also subject to changes of resistance under humid conditions. The resistance of the metallized (film) resistor is much more stable with changes of frequency than the composition type. As the working frequency is increased, composition designs are subject to two opposing effects. First, the normal skin effect tending to increase the resistance; and, second, the capacitance between partially insulated conducting particles tending to reduce the effective resistance. The latter predominates and the higher values of composition resistor show a marked drop in resistance at R.F. compared with the D.C. value.

The common power ratings are ¼, ½, 1, 2 and 3 W, but it should be noted that, for high values of resistance, the voltage rating is the limiting factor because the voltage required to reach full power loading is in excess of the safe permissible voltage gradient. The maximum permissible voltage is of the order of 250 V for the smallest size, rising to 1,500 V for the largest. The value of resistance and tolerance is usually indicated by bands of coloured paint (see COLOUR CODE).

Fixed *wire-wound* resistors (Fig. 32) fall into two categories: low-dissipation precision designs, and those capable of high power dissipation. The former are usually wound on a plastic or ceramic former or spool, using an enamelled or textile-covered nickel-copper alloy wire (see EUREKA WIRE). Various methods of winding are used in manufacture with the object of reducing the residual reactance. One method is known as DUOLATERAL WINDING (q.v.). Resistors for precision measuring equipment usually have the wire wound on to a flat rectangular former by the Ayrton-Perry method (Fig. 33).

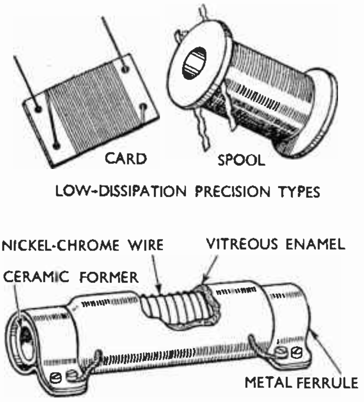


Fig. 32. Examples of low-dissipation and high-dissipation types of wire-wound fixed resistor.

Above a 3-W rating, a non-insulated wire, usually of nickel-chrome alloy (see RESISTANCE ALLOY), is wound with spaced turns on to a ceramic tube provided with ferrules, screws, or lead-out wires. The wound resistor is protected either with lacquer or with vitreous enamel. The latter allows a high wattage rating because the permissible surface temperature is 250 deg. C. compared with only 130 deg. C. for lacquer. This high surface temperature and its effect upon neighbouring components must be borne in mind when arranging the lay-out of the components of a circuit. So that there may be maximum cooling by convection currents of air, the resistors should be mounted vertically and spaced apart. Hollow types should not have the ends closed.

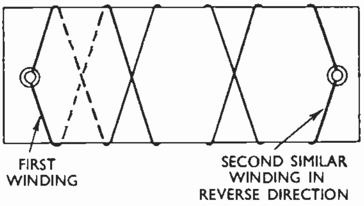


Fig. 33. Principle of the Ayrton-Perry method of winding non-inductive resistors for measuring equipment.

Fixed resistors can become either open- or, less frequently, short-circuited in service, but both faults are comparatively rare. Metallized resistors may become open-circuited as a result of overload; wire-wound types, as a result either of overload or of a faulty joint between the wire and the terminal (resistance alloys are difficult to solder and are usually spot-welded). Under certain adverse conditions the wire may possibly corrode and then break.

Occasionally, metallized and composition resistors are found to be "noisy" in service, due to spontaneous fluctuations of resistance, particularly when working near the full power rating. The fault is most troublesome in the coupling circuit between the first and second stages of a multi-stage amplifier. It is also known to cause short-term frequency instability in beat-frequency oscillators.

FLAGPOLE AERIAL. Aerial for use on very high frequencies, consisting of some form of unipole (see QUARTER-WAVE AERIAL) or end-fed half-wave dipole mounted on the end of a pole support which may, in fact, be a robust form of concentric feeder-line connected to the aerial. See HALF-WAVE DIPOLE, VOLTAGE-FED AERIAL.

FLARE. Term, usually applied to the shape of a loudspeaker or gramophone horn, implying that the cross-sectional area increases with increase in distance from the throat.

FLASH ARC. Arc which may form between the electrodes of a power valve (notably when the anode voltages are several kilovolts); obviously an unwanted condition which may well destroy the valve if it persists. In the early developments of the water-cooled valve, in which anode voltage was 5–12 kV, it was noticed that the anode current momentarily rose to hundreds of times its normal value and at the same time a bright flash occurred inside the valve; the overload breakers of the power-supply system could not act quickly enough to prevent considerable damage to valves and meters. It was supposed that these flash arcs were caused by tiny roughnesses on the inner surface of the anode; the concentration of electric field around these minute points caused ionization of the residual gas, while the arc, when it started, released more gas from the electrodes and so maintained itself. The effect no longer takes place, thanks to care in manufacture and a knowledge of what precautions to take against it. See IONIZATION, SPARK.

FLASHING. Part of the process of activation of a valve cathode. It consists in raising the cathode temperature to a high value for a short time. For instance, thoriated-tungsten filaments are flashed at 2,700 deg. K. for one or two minutes; the filament is then "glowed" at a little over 2,000 deg. K. for a few more minutes. The processes involved vary in all sorts of ways, but flashing invariably implies the raising of the cathode temperature to a higher value than used in normal working. See ACTIVATION.

FLAT-TOP AERIAL. Aerial of which a major part is horizontal, as in the inverted-L type.

FLAT TUNING. Relative term indicating that the resonance graph of a circuit or piece of apparatus is not sufficiently sharply peaked or has too-gently sloping sides to serve its intended purpose satisfactorily. The resulting poor selectivity is characteristic of circuits of high decrement. See RESONANCE, SELECTIVITY.

F-LAYER. Region of ionized gases which exists at a variable height of 100–250 miles above the surface of the earth and was discovered by Appleton in 1925. In this region the pressure of the gases—which are probably mostly helium—is very low, and the ionization is very intense. The ionizing agent is ultra-violet radiation from the sun. Because of the low gas pressure in the F-layer, it is much less dependent on the ionizing influence than is the E-layer, in which the gas pressure is much higher. Recombination of the ions in the F-layer usually takes several hours after the sun has set, and re-ionization occurs very rapidly after sunrise.

As the formation of the F-layer depends upon the sun, its height and density vary diurnally, seasonally, and in accordance with sunspot activity. During the daytime the F-layer splits into two separate layers, designated F1 and F2; and during the night the F1, which is the lower sub-layer, disappears, leaving only the F2-layer.

The F-layer is responsible for the reflection of most waves in the high-frequency band, the critical frequency being higher during the day than at night time and lower in winter than in summer. See CRITICAL FREQUENCY, HIGH-FREQUENCY WAVE, IONOSPHERE.

FLEMING VALVE. Diode named after Sir Ambrose Fleming, who first showed that a diode could be used for the rectification of radio-frequency signals; a D.C. meter could thus be used to measure them. The term is no longer used. See DETECTION, DIODE, EDISON EFFECT, RECTIFIER.

FLEWELLING CIRCUIT. Super-regenerative circuit (Fig. 34) in which the quenching action is obtained from a grid-leak howl adjusted to a frequency near the upper limit of audibility. A grid-leak howl is due to the negative charge on the grid of a self-oscillating valve provided with grid capacitor and leak, this charge first building-up to the point at which it stops the valve from oscillating, then leaking away so that the valve re-starts.

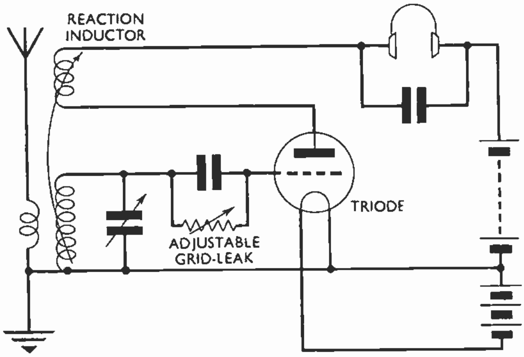


Fig. 34. Simplified diagram of the Flewelling circuit incorporating a variable grid-leak adjustment of the quenching frequency.

FLICKER EFFECT. In a valve, effect associated with shot noise. Flicker effect is caused by an intermittent change of emission at different places on the surface of the cathode, resulting in changes of electrode current. The consequent irregularities in output voltage are heard as noise from a high-gain amplifier. See SHOT EFFECT.

FLIP-FLOP CIRCUIT. Name popularly given to a MULTIVIBRATOR or RELAXATION OSCILLATOR.

FLOATING-CARRIER MODULATION. Modulation in which the amplitude of the carrier wave varies over large values according to the amplitude of the modulating wave, the modulation factor remaining substantially constant. The ratio of the sideband-wave amplitudes to the carrier amplitude remains constant, and the modulation envelope increases and decreases according to the variations of the modulating wave.

FLOATING-CARRIER MODULATOR. Modulator designed to vary the amplitude of both carrier and sideband waves in proportion to the instantaneous amplitude of the modulating wave. The proportionality is not exact, because, with no modulation, the carrier-wave amplitude is small but none the less finite. Fig. 35 shows a form of floating-carrier modulator. As the amplitude of the modulating wave increases, the inductor in the mains supply to the mains unit is more highly magnetized by the increased current taken by the modulating-wave amplifier. This decreases its impedance and raises the high-tension supply to the modulated amplifier, which, in turn, increases the carrier-wave amplitude. The sideband waves are similarly increased by the greater output from the modulating-wave amplifier. See AMPLITUDE MODULATION, FLOATING-CARRIER MODULATION, MAINS UNIT.

FLOATING SCREEN-GRID BIAS. Screen-grid bias supplied through a resistor from the high-tension supply. Fig. 36 distinguishes what is called floating screen-grid bias from the method in which a potential divider is used. In the latter circuit, variations in the screen-grid slope resistance or its impedance cause smaller changes in screen-grid voltage than when the floating-bias arrangement is used.

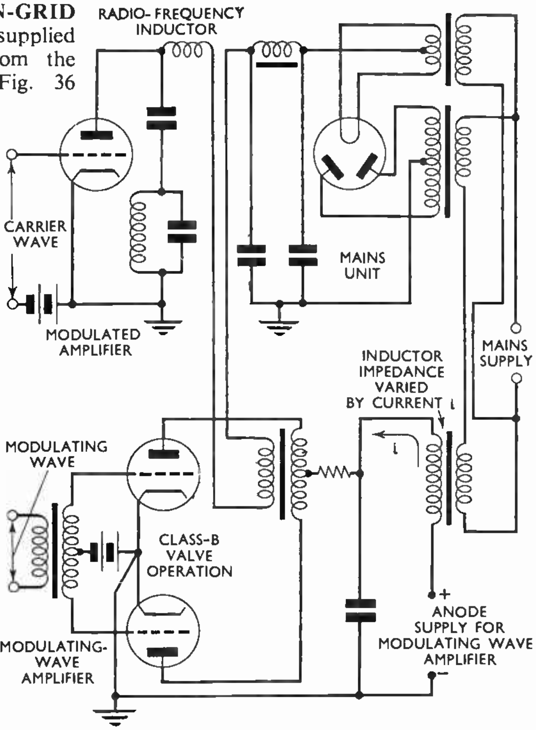


Fig. 35. Form of floating-carrier modulator. Increase in the modulating-wave amplitude reduces the impedance of an inductor in the mains-supply circuit to the mains unit; this is due to an increase in current *i*, corresponding to the reduced impedance, taken by the amplifier. As a result, the H.T. supply to the modulated amplifier is raised and the carrier-wave amplitude is increased.

Fig. 36c shows a circuit convenient when negative feedback is used. This circuit arrangement ensures that the variation of cathode potential due to

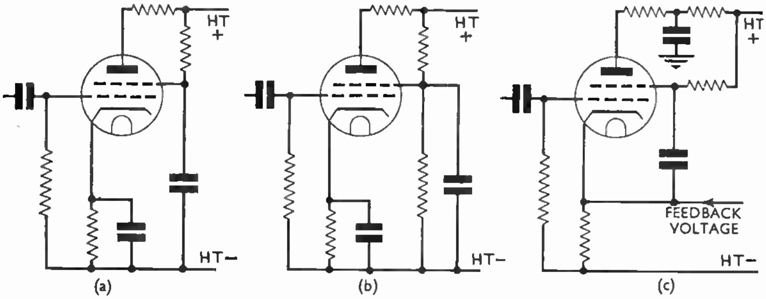


Fig. 36. Circuit arrangements in which (*a*) screen-grid bias may vary with variations in screen-grid slope resistance, and (*b*) bias is held more constant; (c) is a negative-feedback arrangement providing a floating screen-grid bias without introducing an alternating p.d. between screen grid and cathode.

feedback is communicated to the screen grid, so that the screen-grid/cathode potential remains constant. See AMPLIFIER, NEGATIVE FEEDBACK.

FLUCTUATION NOISE. See SET NOISE, SHOT EFFECT, THERMAL-AGITATION VOLTAGE.

FLUORESCENT SCREEN. Specially prepared surface of a cathode-ray tube which becomes luminescent when bombarded by an electron beam. See CATHODE-RAY TUBE.

FLY-BACK. In a cathode-ray tube, the return of the spot from the end of a trace to the starting point. This return is usually very rapid compared with the velocity of the forward trace. In television it is the rapid return of the spot from the end of one line or frame to the commencement of the next. See CATHODE-RAY TUBE.

FLYING-SPOT SYSTEM. Television system in which the scene to be sent out is rapidly scanned by a spot of light, the light reflected from successive parts of the scene being measured by a photocell.

FOCUSING. In a cathode-ray tube, the converging of the electron beam on a required area by electrostatic or magnetic means, or by the ionizing action of residual gas in the tube. See ELECTROSTATIC FOCUSING, GAS FOCUSING, MAGNETIC FOCUSING.

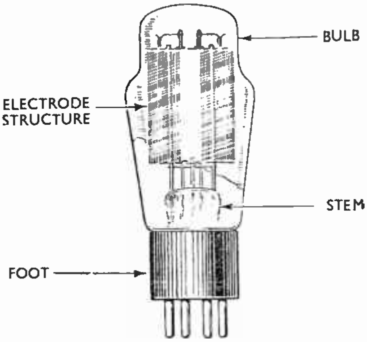


Fig. 37. Foot of a valve distinguished from the other three principal parts; the electrode structure in the example is that of a full-wave rectifier.

FOCUSING COIL. In a cathode-ray tube using magnetic focusing, the coil which focuses the beam by virtue of the magnetic field resulting from the direct current applied to the coil. See MAGNETIC FOCUSING.

FOCUSING ELECTRODE. In a cathode-ray tube or similar device, the electrode which controls the focus by virtue of the potential applied to the electrode. If this potential is variable, the focus is adjustable. See ELECTRON BEAM, ELECTROSTATIC FOCUSING.

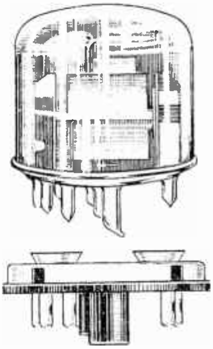


Fig. 38. An example of footless construction; a triode-hexode frequency-changer with electrode structure horizontally mounted on a glass disc.

FOOT. Part of a valve where the connexions to the electrodes are brought through to pins (Fig. 37). The pins fit into the valve holder. See FOOTLESS CONSTRUCTION.

FOOTLESS CONSTRUCTION. Term used to denote the method of bringing out the electrode connexions from a valve so that the capacitance between electrode connexions shall be less than when a foot is used (Fig. 38).

FOOT-POUND. British unit of work. It is the amount of work done when the point of application of a force of 1 lb. moves through a distance of 1 ft. in the direction of the force.

FORCED OSCILLATIONS. Oscillations which are maintained by a source of energy supply external to the oscillating circuit or system, and which have a frequency determined by this source of supply.

FORMER. Carrier or support, usually of insulating material, on which a coil of wire may be wound. For air-cored inductors it is usually circular in section, often a hollow tube. For resistors it may be circular or it may consist of a thin strip of rectangular section. A former with end-flanges or cheeks is called a spool. See FIXED INDUCTOR, FIXED RESISTOR, TRANSFORMER.

FORTUITOUS DISTORTION. Distortion due to irregularities in any part of a circuit or apparatus; in other words, distortion which cannot be classified. See DISTORTION.

FOUR-ELECTRODE VALVE. Synonym for TETRODE.

FOURIER ANALYSIS. Process of determining the number, amplitude, frequency and phase of the components in a given wave form. The French mathematician Fourier (1768–1830) showed that it was possible to synthesize any given repetitive wave form by adding together a number of sinusoidal wave forms, known as components or harmonics, of appropriate amplitude, frequency and phase. The components have frequencies which are simple multiples of the repetition frequency of the given wave form, which is known as the fundamental frequency.

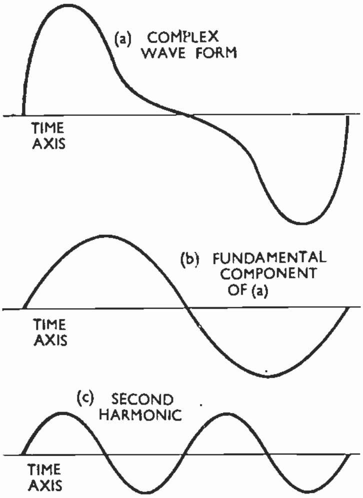


Fig. 39. Fourier analysis is a process of splitting up a complex wave form into a number of simple sine waves. In this diagram, for example, wave (*a*) is produced by mixing together the two waves (*b*) and (c).

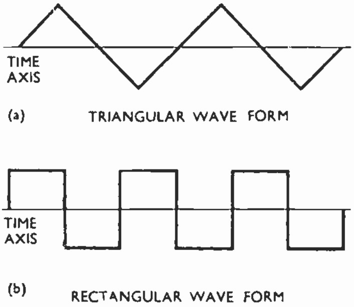


Fig. 40. It can be shown by Fourier analysis that an infinite number of harmonics is present in a wave such as (*a*) or (*b*); an approximation to a given wave form can be obtained, however, by adding the first 20 or so harmonics to the fundamental.

Wave forms without any abrupt changes in gradient have few components. For example, the wave form of Fig. 39a has only two components, and they are illustrated in Figs. 39b and c. The component in Fig. 39b has the same frequency as the original wave form and is a fundamental component, whereas the wave form of Fig. 39c has a frequency twice as great, and is known as a second harmonic.

It is possible for certain components (a fundamental even) to be missing from the results of a Fourier analysis; for example, only the even harmonics, 2nd, 4th, 6th, etc., may be present, the fundamental being absent. Something can be learnt of the harmonic composition of a wave by inspection of its shape. For instance, waves which are symmetrical about the time axis contain only odd harmonics, and those which are asymmetrical must contain some even harmonics, although odd ones may be present as well.

If a wave form has sharp changes in gradient, such as the triangular wave form (Fig. 40a), or the rectangular one of Fig. 40b, an infinite number of harmonics is present, but a good approximation to the given shape can be obtained by summation of the fundamental and, say, the first 20 harmonics. The greater the number of harmonics added, the more nearly does the result approximate to the triangular or rectangular shape.

Because of the large number of harmonics present, potentials of rectangular wave form are very useful for testing the linearity and frequency response of amplifiers. If the amplifier is good, its output wave form will be a good copy of the input wave form, having sharp corners; if the high-frequency response is poor, the upper harmonics are lost and the output wave form has rounded corners. But if the amplifier suffers from phase distortion at certain frequencies, the rectangular shape of the wave form is destroyed.

The human ear is able to make a Fourier analysis of complex sound waves to which it responds (see SPEECH AND HEARING), and it is able to appreciate the number and relative amplitudes of the components; but, in continuous sounds, it cannot detect any changes in the relative phases of the components. By changing these phases, it is possible to produce differing wave forms which sound the same to the ear.

FOUR-TERMINAL TRANSMISSION NETWORK. Synonym for QUADRIPOLE.

FOUR-WIRE CIRCUIT. Circuit used for two-way communication consisting of two pairs of wires, each pair of wires carrying a one-way communication in opposite directions. The arrangement overcomes difficulties that are experienced with a two-wire repeater designed to amplify speech in either direction equally, without instability. See TWO-WIRE CIRCUIT.

FRAME. In the cinematograph, one picture unit in the long sequence of units forming the film reel. To form a motion picture, the frames are projected on a screen in sequence and fast enough to give, through persistence of vision, the illusion of movement.

Between each frame, the light from the projector is interrupted by a mask so that the screen goes dark. If the frequency of frame interruption is not high enough, flicker results.

The term "frame" was formerly also used in connexion with television, but this is now deprecated; to avoid confusion, the term "television field" has been adopted.

See also under FIELD in the Appendix.

FRAME AERIAL. Synonym for LOOP-AERIAL.

FRAME DIRECTION-FINDER. Synonym for LOOP DIRECTION-FINDER. See also DIRECTION FINDER.

FRAME-FREQUENCY. Frequency, in television, at which frames are repeated. In sequential scanning this must be not less than 16 per second, and is preferably 20 or over if flicker is to be avoided. In British high-definition television, which employs interlaced scanning, 50 frames per second are transmitted, although the picture-frequency is only 25 per second. See INTERLACED SCANNING, PICTURE-FREQUENCY, SEQUENTIAL SCANNING.

FRAME-SYNCHRONIZING SIGNAL. Series of impulses radiated by a television sender at the end of each frame. In a sequential-scanning system there is one such signal per picture, but in an interlaced system, such as that employed in the present B.B.C. high-definition service, there are two frame-synchronizing signals per picture.

The purpose of the frame-synchronizing signal is to ensure that the frame scanning in all receivers is precisely in step with that at the sender.

For satisfactory results, the receiver frame-frequency must be precisely equal to that of the sender; in addition, the two frequencies must be in phase. As the pictures in most modern television receivers are displayed on the screens of cathode-ray tubes, the need for frame-synchronizing impulses will here be explained in terms of such receivers.

The receiver frame-scanning generator is deliberately adjusted to operate at a frequency lower than the sender frame-frequency, and the frame-synchronizing signals are arranged to trip, or trigger, the receiver generator to cause the scanning spot to fly back to the top of the screen before it has completed its natural cycle. The spot then traverses the screen again, and is again returned to the top by the next frame-synchronizing impulse. In this way precise synchronism can be obtained.

There is usually a small range of receiver frame-generator frequency within which the frame-synchronizing signals are fully effective in securing synchronism.

The line-scanning generator is similarly "locked" at the correct frequency by line-synchronizing impulses radiated by the sender at the end of each line, and it is necessary that line scanning should continue normally throughout the duration of the frame-synchronizing impulse; if the line-scanning generator were to run free during the frame-synchronizing impulse, the generator would take an appreciable time to lock on the resumption of line-synchronizing signals, with the result that the first few lines of each frame would be distorted.

Thus the frame-synchronizing signal does not consist of a single broad pulse but is subdivided into a number of broad pulses in such a manner that there is a component at line frequency which can be used to trip the line-scanning generator to ensure continuity of line scanning during the frame-synchronizing signal. See BLOCKING OSCILLATOR, FRAMING, FRAMING OSCILLATOR.

FRAMING. Process of adjusting, in television, the frame synchronizing so that the picture falls properly on the vision screen. If the frame-frequency is out of synchronization with the sender frame-frequency, the picture may appear cut in two, with the lower portion at the top and the upper portion at the bottom of the screen, as indicated in Fig. 41.

Fig. 41. Example of the effect of incorrect framing on a received television picture.

This effect is caused by arrival of the frame-synchronizing impulse before the frame scan is complete. Under these conditions, the impulse will not trigger the oscillator and the frame time base will work on its own, the picture then drifting up or down the screen. Alteration of the scanning speed will allow the frames to drift until the time-base can be synchronized with the frame-synchronizing impulse.

FRAMING OSCILLATOR. Time-base circuit employing some form of saw-tooth generator providing the wave form necessary for deflecting the cathode ray in the vertical, or frame, direction. In modern television receivers a blocking oscillator or thyratron is almost universally employed.

At a predetermined instant, the length of scan being sufficient to have moved the spot right down the screen, the frame-synchronizing impulse is applied to the oscillator; this causes the cathode-ray beam to return rapidly to the original position. The process is repeated for every frame. See BLOCKING OSCILLATOR.

FRANKLIN AERIAL. Directive aerial employing multiple elements uniformly spaced along a line at right-angles to that of maximum radiation; it is thus a broadside array. The elements are vertical, several half-waves in length, radiation from alternate half-wave sections being suppressed (see HALF-WAVE SUPPRESSOR COIL). The array is characterized by giving maximum radiation in a horizontal direction.

FREE GRID BIAS. Term, now obsolete, describing any system for obtaining a grid bias without the use of a separate source of voltage such as a bias battery. The introduction of the indirectly heated cathode was of particular advantage to the circuit designer because it allowed him freedom to use a common heater source and yet supply different valves with different grid bias. See AUTOMATIC GRID-BIAS, CATHODE BIAS, GRID BIAS.

FREE OSCILLATIONS. Oscillations in a system containing capacitance, inductance and resistance, the values of which constants determine the frequency of the oscillations.

FREQUENCY. Measure of the rate at which a current or voltage alternates, or at which an electromagnetic radiation passes through one cycle. Unless a unit is specified, frequencies are assumed to be stated in cycles per second (c/s). The frequencies of low and medium rates of alternation, such as those of alternating currents used for power and sound reproduction, are conveniently stated in cycles per second, but as radio frequencies would involve clumsy figures in this unit they are stated in kilocycles per second and megacycles per second. A kilocycle is a thousand cycles, a megacycle is a million cycles.

Frequency is a fundamental characteristic of an alternating current, and has a direct bearing on the properties of the current and the methods used in handling it. The frequency is even more important in the case of high-frequency currents and the electromagnetic waves which they generate.

It is useful to have some mental picture of the whole spectrum of frequencies in common use. From about 25 c/s up to something of the order of 10,000–15,000 c/s, currents represent audible tones or harmonics and are described as audio-frequency.

Higher frequencies enter the radio-frequency range; the longest wavelengths which have been used are, in fact, equivalent to frequencies at the top of the audio-frequency scale. The medium-wave broadcasting waveband embraces frequencies ranging from about 550 to, perhaps, 1,600 kc/s.

Next is the range of short waves; the frequency corresponding to a wavelength of 100 metres is 3 Mc/s, and that corresponding to 10 metres is 30 Mc/s. In the microwave range, 10 cm. corresponds to a frequency of 3,000 Mc/s, and 1-cm. waves have a frequency of 30,000 Mc/s. Waves of millimetre wavelength may necessitate the use of a still bigger frequency unit; a wavelength of a millimetre corresponds to a frequency of 300,000 Mc/s.

A frequency of 300,000,000,000 c/s is certainly an impressive figure, but it is only part of the scale of the electromagnetic radiations which are known. At the wavelength of infra-red or heat rays, the frequency is of an order that calls for eight noughts even when expressed in megacycles, and visible light is of a still greater frequency; X-rays and gamma rays have frequencies thousands of times higher still. See ALTERNATING CURRENT, WAVELENGTH.

FREQUENCY BAND. Term expressed quantitively by specifying two frequencies which are the limits of the range of frequencies lying between them. The term is used a great deal in connexion with transmission theory and practice. Modulation of a carrier produces sideband waves of different frequencies and these can be said to lie within a frequency band. See CUT-OFF FREQUENCY, SIDEBAND WAVE.

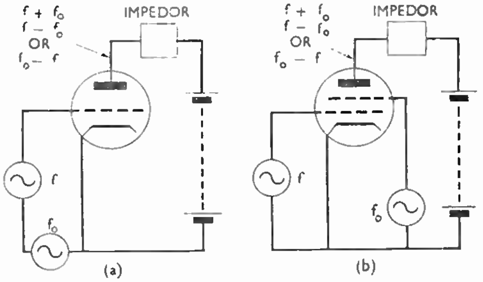


Fig. 42. Simplified diagrams which illustrate the operation of frequency-changer valves; (*a*) shows the circuit of non-linear and (*b*) that of linear modulation systems.

FREQUENCY-CHANGE OSCILLATOR. Synonym for BEAT OSCILLATOR.

FREQUENCY-CHANGER. Amplitude modulator of any kind, including any circuit which produces beating. See BEATING, FREQUENCY-CHANGER VALVE, MODULATOR.

FREQUENCY-CHANGER VALVE. Valve producing, at one electrode, waves which have a frequency that is different from those of waves applied to another electrode. Locally generated oscillations are essential to the process (see FREQUENCY-CHANGING). A distinction must be drawn between the circuits of a frequency-changer valve and those of, for instance, a multivibrator. Both circuits produce waves of changed frequency, but the multivibrator and similar devices are frequency multipliers, not frequency changers (see FREQUENCY MULTIPLICATION).

The frequency-changer, in using a local oscillator, is not limited to producing harmonic waves from a fundamental as is the multivibrator; given locally generated oscillators, the frequency-changer can produce from one wave a new wave of any frequency, within obvious circuit limitations (see LOCAL OSCILLATOR). Frequency-changers are of two types: those which are based on non-linear, or additive, modulation, and those that are based on linear, or multiplicative, modulation (see NON-LINEAR MODULATION).

Fig. 42 shows the distinction, and how, in non-linear modulation, the wave whose frequency is to be changed is connected in series with the local-oscillator wave. In contrast, the linear-modulator type of valve must have at least four electrodes so that the anode current may be modulated by the two waves of different frequency which are applied to different grids.

The frequency-changer valve is thus essentially a modulator, and frequency changing is a process of modulation (see MODULATION). In other words, if f is the frequency of the wave which is to be changed in frequency and f_o the frequency of the local oscillator, then the waves of changed frequency are sideband waves. These sideband waves are of frequencies $(f+f_o)$ and $(f-f_o)$ or (f_o-f), depending on whether f is greater or less than f_o (see SIDEBAND).

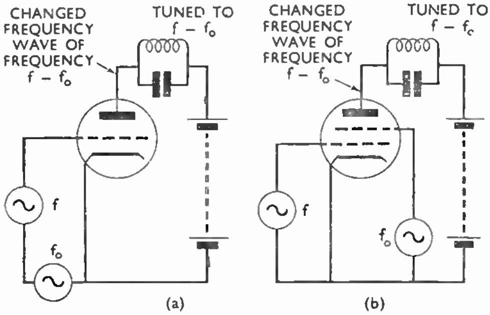


Fig. 43. Frequency-changing circuits in each of which a filter (shown as a tuned circuit) attenuates all but the chosen frequency-changed wave; (*a*) is for non-linear and (*b*) for linear modulation.

In all frequency-changers it is probable that besides the sideband waves, their harmonics and other modulation products, the local-oscillator wave and the input waves will also appear in the output. For this reason a filter (Fig. 43) must be used in the output circuit to attenuate all waves but that which is chosen as the frequency-changed wave. This is commonly a first-order sideband.

The non-linear modulator type of frequency-changer (Fig. 42a and Fig. 43a) is sometimes called an anode-detector frequency-changer (or plate detector in American textbooks). It has the advantage of causing less background noise, and the simple triode may be used. The non-linear type of frequency-changer has the disadvantage that the two oscillations, when close together in frequency, may, in some circumstances, come into synchronism (see COGGING). For this reason most superheterodyne receivers use the linear-modulator type of frequency-changer. The basic form of this valve is a tetrode (Fig. 42b and Fig. 43b).

The multiplication of electrodes to form hexodes, heptodes, octodes and triode-hexodes is necessary in order to isolate the signal-frequency and oscillator circuits from one another by minimizing inter-electrode capacitance (see INTER-ELECTRODE CAPACITANCE); and, secondly, to provide electrodes for the generation of oscillations in the valve itself, thus dispensing with the necessity for another valve to generate the (local) oscillations essential to frequency-changing. Thus Fig. 44 shows several possible variations of the frequency-changer valve in its different forms. It is essential to realize that all are based upon the principle of linear modulation, as shown in Fig. 43b.

In Fig. 44a the hexode is used with a local oscillator, the screen grids G_2 and G_4 shielding the control grid from the grid energized from the local oscillator. In Fig. 44b the heptode generates its own oscillations. In Fig. 44c the triode-hexode consists of a hexode used for frequency-changing and a separate triode for generating the local oscillations, all the electrodes being in one bulb and a common cathode sufficing for both oscillator and frequency-changer. Variations upon the basic schemes of Fig. 44 are used; for example, suppressor grids may be

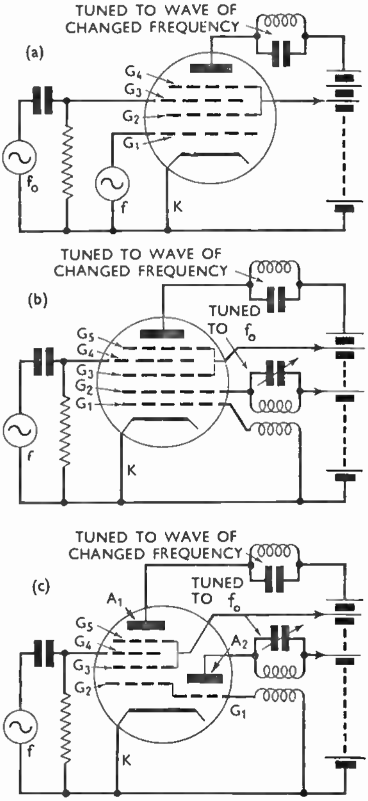


Fig. 44. Frequency-changer valves shown are: (*a*) a hexode using an external local oscillator f_0, (*b*) a heptode which illustrates how oscillations may be generated in the frequency-changer valve, and (c) a triode-hexode in which the triode generates oscillations by the use of a cathode common to the hexode.

used to give frequency-changers pentode characteristics.

Frequency-changer valves are designed as variable-mu valves. This is advantageous in certain cases. Thus, by using the grid-leak connexion of Fig. 44a, changes of oscillator voltage tend to alter the conversion conductance in a compensatory way, thus tending to keep constant the level of the wave of changed frequency. See BEATING, BEAT RECEPTION, CONVERSION CONDUCTANCE, VIRTUAL CATHODE.

FREQUENCY-CHANGING. Process in which a wave of one frequency has another frequency added to, or subtracted from, it to produce a wave of changed frequency. The process of modulation is essential to that of frequency-changing. Thus, if a wave of frequency f_1 is amplitude-modulated by a wave of frequency f_2, the modulated wave contains waves of frequencies $f_1 + f_2$ and $f_1 - f_2$ (or $f_2 - f_1$) as well as f_1. In suppressed-carrier modulation, the modulated wave contains waves of frequencies $f_1 + f_2$ and $f_1 - f_2$ (or $f_2 - f_1$). The waves of frequency $f_1 + f_2$ and $f_1 - f_2$ (or $f_2 - f_1$) are waves of changed frequency; in fact, they are sideband waves.

Thus, basic to all frequency-changing is a process of amplitude modulation (though any other form of modulation would suffice, amplitude modulation is generally used). In a superheterodyne receiver, the signal wave is a modulated wave containing frequencies $f_c + af_m$, $f_c - af_m$, $f_c + bf_m$, $f_c - bf_m$, and so on, where f_c is the carrier wave and af_m, bf_m the modulating-wave frequencies. The frequency-changing in the frequency-changer valve produces, among others, waves of frequency $f_c - f_o + af_m$, $f_c - f_o - af_m$, and so on, where f_o is the oscillator frequency. Taking $(f_c - f_o) = f_{1c}$, we see that a new carrier wave with a frequency of f_{1c} is produced; in other words, the modulated wave has its carrier frequency changed by subtracting a constant frequency from the signal carrier wave. The new modulated wave contains waves of frequency $f_{1c} + af_m$, $f_{1c} - af_m$, $f_{1c} + bf_m$, $f_{1c} - bf_m$ and so on. Many waves are produced in frequency-changing, but those wanted are selected by a filter.

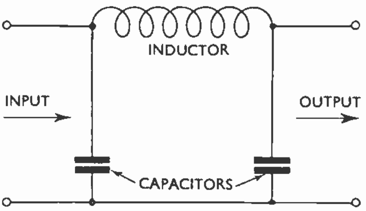


Fig. 45. Frequency-discriminating filter; the values of the capacitors and inductors are governed by the frequency of operation required, the inductor sometimes being iron-cored.

Beating constitutes frequency-changing and can be classified as a system of amplitude modulation (of a non-linear type). Circuits to produce non-linear modulation and beating are identical, except that the wave selected by the filter is different. Modulation is common to both. Thus frequency-changing, in all its aspects, is based on modulation. See AMPLITUDE MODULATION, BEATING, FREQUENCY-CHANGER, FREQUENCY-CHANGER VALVE, MODULATION, SIDEBAND.

FREQUENCY CONVERSION. Synonym for FREQUENCY-CHANGING.

FREQUENCY CONVERTER. Synonym for FREQUENCY-CHANGER.

FREQUENCY DEMULTIPLICATION. See FREQUENCY DIVISION.

FREQUENCY DEVIATION. Maximum value of the frequency swing of a frequency-modulated wave. Maximum value occurs when the modulating wave has its maximum amplitude. See FREQUENCY MODULATION.

FREQUENCY-DISCRIMINATING FILTER. Network containing reactances, and perhaps resistances, designed to pass a particular frequency or frequency band more easily than other frequencies. Fig. 45 illustrates a low-pass filter which allows low frequencies to pass with little attenuation but discriminates against high frequencies. See BAND-PASS FILTER, FILTER, HIGH-PASS FILTER, LOW-PASS FILTER.

FREQUENCY DISCRIMINATOR. Discriminator in which the output is substantially proportional to the variation of the frequency of a wave from a mean value. In many circuit applications, notably automatic tuning and frequency modulation, the frequency of the waves generated by an oscillator must be maintained substantially constant. A frequency discriminator does this, and one form of such a discriminator is shown in Fig. 50. The term is used to describe any device which converts a frequency-modulated wave into an amplitude-modulated wave. See AUTOMATIC TUNING-CONTROL, FREQUENCY MODULATOR.

FREQUENCY DISTORTION. Term commonly used for ATTENUATION DISTORTION.

FREQUENCY-DIVIDER. Device which produces, at its output terminals, a wave which has $1/n$ times the frequency of a wave applied to its input terminals, n being a whole number. The circuit of Fig. 46 illustrates one form of frequency-divider.

The gain of the amplifier must be sufficient to start the process, which is otherwise automatic. See FREQUENCY DIVISION.

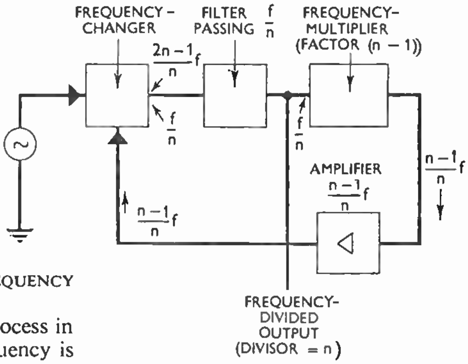


Fig. 46. Schematic diagram of one form of frequency-divider, where f is the frequency of the wave applied to the input terminals of the frequency-changer, and f/n is the frequency of the output, n being a whole number.

FREQUENCY DIVISION. Process in which a wave of a given frequency is made to produce a wave of lower frequency, the ratio of the lower to the higher frequency being a whole number. Thus, if the original wave has a frequency f, the frequency-divided wave has a frequency f/n, where n is a whole number. See FREQUENCY-DIVIDER.

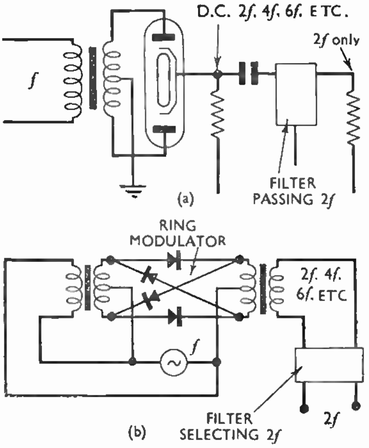


Fig. 47. Two ways in which a frequency-doubler may be set up: (*a*) by means of a full-wave rectifying valve, and (*b*) by a modulation process.

FREQUENCY-DOUBLER. Device which produces a wave at its output terminals that is exactly twice the frequency of a wave applied to its input terminals. Any device producing a strong second harmonic of a wave is a frequency-doubler. Any modulator, in which the modulating and carrier waves have the same frequency, is also a frequency-doubler. A filter is used to select the wave of doubled frequency (Fig. 47). See FREQUENCY-CHANGING.

FREQUENCY-DOUBLING. Process occurring in any device in which the output contains a strongly marked component having twice the frequency of the input signal. A full-wave rectifier gives frequency-doubling; so does an electromagnetic transducer (a power-transformer between electrical, mechanical or acoustic communication-system components) when the polarizing current is inadequate. Loudspeakers with straight-sided diaphragms are prone to frequency-doubling, and exponentially curved cones were introduced to minimize this effect. See FREQUENCY-DOUBLER.

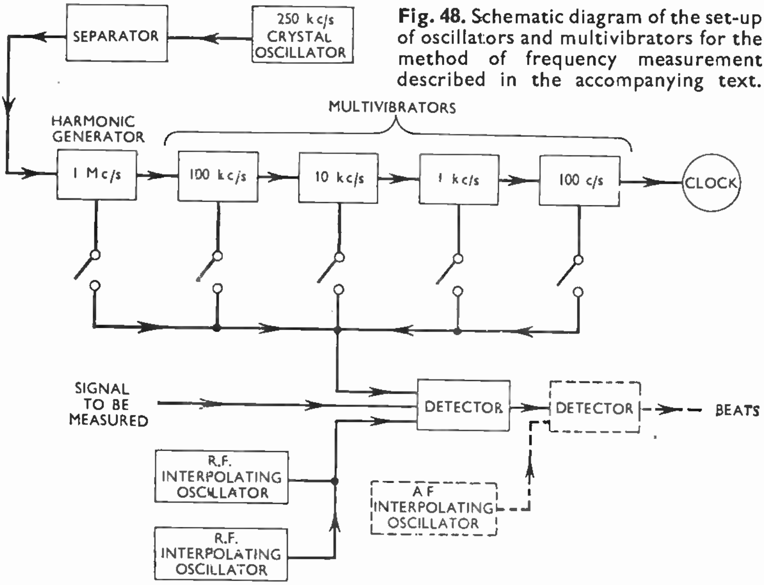


Fig. 48. Schematic diagram of the set-up of oscillators and multivibrators for the method of frequency measurement described in the accompanying text.

FREQUENCY MEASUREMENT. Term usually implying the act of measuring the frequency of electromagnetic waves radiated by a sender; but it may also be applied to audio frequencies. It is more usual to determine the frequency of an electromagnetic wave than its wavelength. Wavelength and frequency are related thus:

$$\text{frequency} = \frac{\text{velocity}}{\text{wavelength}}.$$

The velocity is fixed and equal to 3×10^{10} cm./sec. Hence it is easy to determine frequency if the wavelength is known, and vice versa. For example, the wavelength corresponding to 1,500 kc/s is given by $\frac{3 \times 10^{10}}{1{,}500 \times 10^3} = 2 \times 10^4$ cm. = 200 metres.

Frequency is rarely determined absolutely; it is usually obtained by comparison of the unknown frequency with a known one. The theory of one method of frequency measurement can be understood from Fig. 48. The accuracy of this method depends on the accuracy of the thermostatically controlled quartz-crystal oscillator, and this can give a frequency stability as high as a few parts in a million.

The quartz-crystal oscillator may operate at 250 kc/s, and feeds into a separator stage, the anode circuit of which contains an inductance-capacitance circuit tuned to 1 Mc/s, that is, the fourth harmonic of the crystal frequency. The next stage is a harmonic generator operating with an input of 1 Mc/s, and providing an output very rich in harmonics.

Part of the harmonic-generator output is fed to the input of a multivibrator, the constants of which are chosen so that the fundamental frequency of oscillation is approximately 100 kc/s. By this means the 1-Mc/s output "locks" the frequency of the multivibrator, and its output contains components spaced accurately at 100-kc/s intervals over a very wide frequency range.

Part of the output of the 100-kc/s multivibrator is used in a similar circuit arrangement to lock the frequency of a 10-kc/s multivibrator. This circuit arrangement is continued as far as a 100-c/s multivibrator, and part of the output of this is sometimes used to control an electric clock. The accuracy of time-keeping by the clock thus gives a check on the accuracy of the entire equipment.

The equipment also includes an oscillator with variable tuning known as an interpolating oscillator. Its tuning dial is calibrated in terms of frequency, and its output is fed into a detector stage together with the signal to be measured and the output of the various multivibrators, which may be selected as desired by means of keys.

The measurement is made as follows: it is assumed that the frequency of the signal to be measured is known roughly (from, say, its position on the tuning dial of a receiver). The signal is applied to the detector and the interpolating oscillator is tuned until audible beats between the two signals are obtained at the output of the detector. The interpolating oscillator must now be accurately calibrated at and near this setting by the use of the multivibrators.

First, the interpolating oscillator is accurately calibrated at the nearest multiple of 1 Mc/s by heterodyning it with the output of the 1-Mc/s harmonic generator. Next, the output of the 100-kc/s multivibrator is added and the interpolating oscillator is accurately calibrated at the multiple of 100 kc/s nearest the frequency of the unknown signal. Further multivibrators can be switched in, and the position of the signal to be measured on the dial of the interpolating oscillator can be determined as accurately as desired.

If the frequency of the signal to be measured does not fall within the range of the interpolating oscillator, beats may be obtained between the signal and one of the harmonics of the interpolating oscillator, and the frequency measurement may be carried out as previously described, the final frequency reading being multiplied by the order of the harmonic used.

To minimize this additional labour, two interpolating oscillators are often employed, one covering long and medium waves on fundamental or second harmonic and the other covering the greater part of the short-wave range in a similar manner.

When the frequency has been determined to the nearest kc/s, the measurement may be continued to a greater degree of accuracy with the aid of an accurately calibrated audio-frequency oscillator. To do this, the signal is heterodyned with the nearest multiple of 1 kc/s and the beat note resulting in the detector output is applied to a second detector together with the output of the audio-frequency oscillator, which is adjusted to produce zero beat at the output of the second detector.

The reading of the A.F. oscillator is then noted and is added to or subtracted from the frequency given in the early part of the measurement, depending whether the multiple of 1 kc/s is lower or higher than the frequency to be measured. By this means, frequency determinations that are accurate to within a few parts in a million can be made.

FREQUENCY METER. Synonym for WAVEMETER.

FREQUENCY MODULATION. System of modulation in which the frequency of the carrier wave is changed in accordance with the amplitude of the modulating wave, the amplitude of the frequency-modulated wave remaining unchanged. Fig. 49 shows a sinusoidal modulating wave and the resulting frequency-modulated wave. The important quantities relevant to frequency modulation are: (1) The difference between the carrier-wave frequency and instantaneous frequency of the modulated wave; this is the frequency swing. (2) The maximum value of the frequency swing; this occurs when the modulating wave has its maximum amplitude, and is called the frequency deviation. (3) The ratio of the frequency swing to the frequency of the modulating wave. This is called the modulation index.

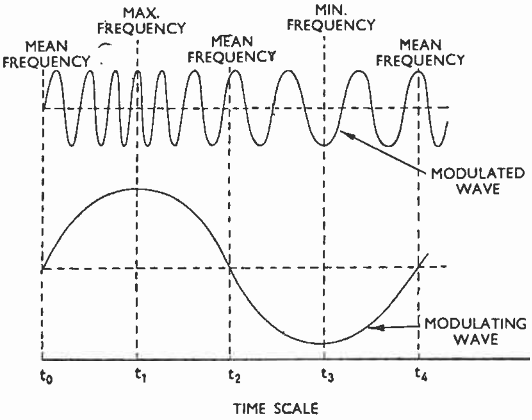


Fig. 49. Diagrams which illustrate the principle of frequency modulation by showing a frequency-modulated wave in relation to the (assumed) sinusoidal modulating wave. They are not, however, representative of quantities used in normal practice.

The sideband waves produced during frequency modulation have frequencies $f_c + f_m$, $f_c - f_m$, $f_c + 2f_m$, $f_c - 2f_m$, $f_c + 3f_m$, $f_c - 3f_m$, and so on to infinity. The amplitude and frequency of the sideband waves is determined by the value of the modulation index. Thus the band of frequencies taken up by a frequency-modulated wave is much greater than that taken up by an amplitude-modulated wave. There are notable advantages in using frequency modulation, in spite of the wider sidebands; for example, the signal-to-noise ratio is improved. See FREQUENCY MODULATOR, PHASE MODULATION, SIDEBAND WAVE.

FREQUENCY MODULATOR. Modulator which changes the frequency of a carrier wave in accordance with the amplitude of a modulating wave. The amplitude of the modulated wave remains substantially constant. Fig. 50 shows a form of frequency modulator using a valve reactor. The input impedance of its terminals *e* and *f* has the nature of an inductance and the value of this inductance is determined by the grid-cathode potential of the valve. Thus the tuned circuit of the oscillator (the valve itself is not shown) is in parallel with what is, in effect, a large inductance.

The value of this inductance is controlled by the voltage on the grid of the valve reactor. This voltage is varied by the modulating wave and so the effective inductance in parallel with the oscillator-tuned circuit changes in accordance with the voltage of the modulating wave. This implies that

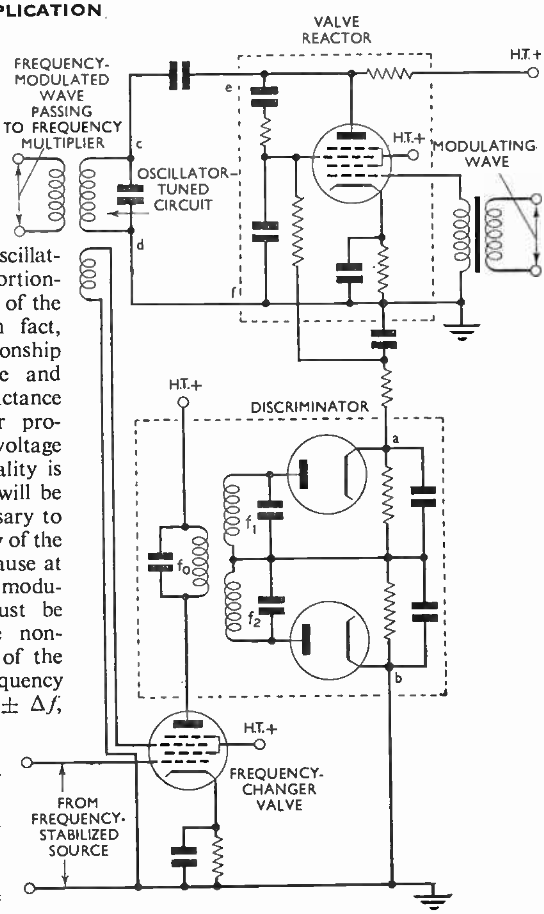


Fig. 50. Frequency modulator using a valve reactor and incorporating arrangements to stabilize the frequency of the oscillator.

the frequency of the oscillating circuit varies proportionately with the voltage of the modulating wave. In fact, the non-linear relationship between grid voltage and effective inductive reactance of the valve reactor prohibits a large grid-voltage change if proportionality is to be maintained. It will be noted that it is necessary to multiply the frequency of the modulated wave, because at the output from the modulator the change must be small owing to the non-linear characteristics of the valve reactor. If a frequency changes from f to $f \pm \Delta f$, multiplying by n produces $nf \pm n\Delta f$.

Such a circuit, by itself, would not in the absence of modulation maintain a constant oscillator frequency. Thus, the slightest change in the constants of the valve reactor would alter the oscillator frequency and the carrier-wave frequency would drift. This is most undesirable, and the discriminator shown in Fig. 50 controls the oscillator frequency within fine limits. The frequency-changer valve produces an output frequency f_0 determined by the difference between a stabilized-frequency source and the oscillator frequency.

The coupled circuits of the discriminator are tuned to frequencies slightly greater and slightly less than f_0. Thus the rectifiers produce potentials across a and b which are zero when f_0 has the correct value. If f_0 rises or falls in frequency due to the oscillator changing its frequency, these steady potentials are developed across a and b in one sense or the other. These potentials change the screen-cathode potential of the valve reactor so as to adjust the inductive impedance across e and f to a value to maintain f_0, and hence the oscillator frequency, at a constant value.

FREQUENCY MULTIPLICATION. Process whereby a wave is produced which is n times the frequency of the wave from which it is produced, n being a whole number. If a wave has a frequency f, it is possible to generate from it waves having frequencies $2f$, $3f$, $4f$ and so on. Any one of these waves is a frequency-multiplied wave and may be selected by a filter. See FREQUENCY-MULTIPLIER.

FREQUENCY-MULTIPLIER. Device which produces a wave of frequency nf at its output terminals when a wave of frequency f is applied to its input terminals, n being a whole number. A recognized form of frequency-multiplier consists of a rectifier which distorts the input wave and a filter which selects the desired harmonic of the distorted wave created (Fig. 51a). The rectification of a wave produces waves having frequencies $2f$, $4f$, $6f$ and so on; any one of these may be selected by a filter. Generally the greater the frequency of the harmonic, the less its amplitude (see FOURIER ANALYSIS). Any distorting device produces harmonics (Fig. 51b). The saw-toothed wave produces frequencies $2f$, $3f$, $4f$, $5f$ and so on. The multivibrator can be used as a frequency multiplier. See FREQUENCY DIVIDER, FREQUENCY MULTIPLICATION, HARMONIC DISTORTION, MULTIVIBRATOR, RECTIFICATION.

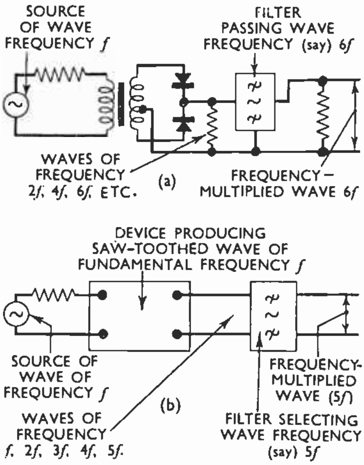


Fig. 51. Circuit of a recognized form of frequency-multiplier (*a*). Harmonics are produced by any distorting device as, for example, that shown at (*b*).

FREQUENCY OF INFINITE ATTENUATION. Frequency at which the attenuation of certain types of filter sections would be infinite if the elements composing the section had zero loss. A filter section of the so-called "m-derived" type is shown in Fig. 52, and this has a frequency of infinite attenuation associated with it. See FILTER.

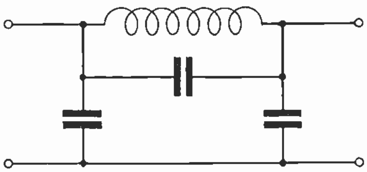


Fig. 52. Diagram of the "m-derived" filter, with which is associated a frequency of infinite attenuation.

FREQUENCY RESPONSE. Variation in gain or loss of a component or piece of apparatus as frequency is varied over its working range. If the gain or loss is not constant, the response characteristic of the component is usually exhibited as a curve obtained by plotting the output against frequency.

FREQUENCY STABILIZATION. Reduction to a minimum of the frequency drift of an oscillator. When oscillation is maintained in a circuit by means of a valve supplied with current from batteries or a mains rectifier, the frequency varies from the moment of switching on.

The magnitude of the frequency deviation, or drift, depends on a number of factors and may be as much as 2,000 parts in a million. An oscillator with a drift as great as this is said to have poor stability, whereas one in which the fluctuations amount to a few parts in a million is said to have great frequency stability, the process of reducing the drift being termed frequency stabilization.

In most practical cases, frequency drift is undesirable or inadmissible. In small laboratory oscillators it reduces the accuracy of calibration, and, in oscillators used as carrier sources in senders, it may cause interference with other radio senders.

For the purpose of listing the chief causes of frequency drift, the oscillator may be regarded as a frequency-determining network and a maintaining system, both of which may cause drift. That due to the maintaining system may be caused by changes of electrode voltages and variations with temperature of the valve characteristics, but it has been established that these factors rarely cause fluctuations in excess of 20 parts in a million.

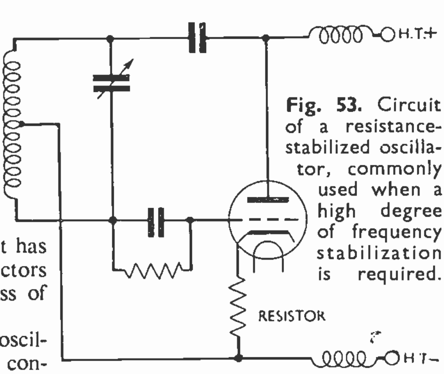


Fig. 53. Circuit of a resistance-stabilized oscillator, commonly used when a high degree of frequency stabilization is required.

The chief cause of drift is the oscillatory circuit itself. This usually consists of an inductor and a capacitor, and any changes in inductance or capacitance cause fluctuations in frequency. Changes in inductance or capacitance as great as 1,000 parts in a million may result from the following factors, given in the order of their relative importance:

- variation in atmospheric temperature;
- temperature variation in the conductor only;
- ageing of the constructional materials; and
- change of atmospheric pressure.

It is the purpose of stabilization to reduce the effects of these factors to a minimum.

The most obvious way of stabilizing inductance is to place the inductor in an oven the temperature of which is automatically kept constant. This method is used in master oscillators employed as carrier sources for senders.

If the temperature of an inductor changes, the resistance, the self-capacitance and the inductance all vary. Although each of these three changes affects the frequency of oscillation, it is the change in inductance which produces the major effect and the purpose of inductance stabilization is to render the inductance independent of temperature.

One method of stabilization is to maintain the dimensions of the inductor as constant as possible, either by applying constraint to conductors having normal expansion properties so as to keep the diameter and length as constant as possible, or by making the former from material having a low expansion coefficient, with special means of retaining adhesion between conductor and former. The logical development of the latter method is by coating the conductor with an electrolytic deposit or by spraying a former of very low temperature coefficient.

A second method of inductance stabilization is by using a design in which the inductance variation caused by a change in the diameter of the coil is corrected automatically by the change in length. This may be obtained by use of a formerless coil in which the conductor is stressed deliberately to give a particular ratio of radial/axial expansion, or by a coil wound on a former having such expansion coefficients in the radial and axial directions as to give compensation.

The capacitance of most commercial

capacitors changes at the rate of 160 parts in a million for a change in temperature of 1 deg. Centigrade. The types consisting of silver deposited on mica are better, and have a change of the order of 40 parts in a million per degree Centigrade It is possible, however, to arrange for the variation of inductance to compensate for the variations in capacitance, and this is quite a satisfactory method of stabilization for an oscillator designed to work at one frequency only.

Capacitors with low temperature coefficients of capacitance can be designed by using iron-nickel alloy plates and frame to eliminate expansion effects, or by using a similar frame, with brass plates sliding in grooves, in order to maintain the area/air-gap ratio constant. Another method is to use a bimetallic expansion device to vary the air-gap so as to compensate for the increase in effective area of the plates.

A capacitor may be stabilized in the same way as an inductor by placing it in a thermostatically controlled oven.

Although the effects of the maintaining circuit on the frequency are not so important as the effect of temperature variation on the oscillatory circuit, it is necessary to adopt some means of stabilization where the highest degree of stability is required. The following are the chief methods of stabilization applied to the maintaining system:

1. The reduction of grid current to a very small value by the application of grid bias, preferably by automatic means.

2. Increasing the anode-circuit resistance either by the use of a valve of high r_a (anode A.C. resistance), or by the insertion of an additional series resistor. This is known as resistance-stabilization and the circuit of an oscillator employing this principle is illustrated in Fig. 53.

3. The use of a tuned circuit with a high C/L (capacitance-to-inductance) ratio. This tends to reduce the harmonic content of the oscillator output and to stabilize frequency.

4. Making the oscillatory circuit of low resistance.

5. Using a stabilizing reactance. An improvement in stability may be obtained by including in the circuit a reactance designed to neutralize the effect of the reactance of the maintaining system.

6. Using a very close coupling between anode and grid circuits.

7. Equalizing the resistance in the inductive and capacitive branches of the oscillatory circuit.

Possibly the best method of stabilizing an oscillator designed to operate at one frequency only is by the use of a quartz crystal to control the frequency. Certainly, this is the only method capable of ensuring stability of the order of a few parts in a million (see CRYSTAL OSCILLATOR).

Alternatively, a device may be designed in which any deviations of frequency from the desired value gives rise automatically to a restoring action which tends to eliminate the deviation. This involves the use of a stabilized oscillator as a frequency standard, and the correction may be applied by mechanical or electrical means. A system in which the inductance or capacitance is varied by mechanical means has the disadvantage of requiring appreciable time for its action, but the electrical system, in which the controlling agent is a potential applied to the grid of a valve, is superior in this respect.

FREQUENCY-STABILIZED OSCILLATOR. Oscillator in which special precautions have been taken to minimize frequency drift from the causes mentioned under the heading FREQUENCY STABILIZATION. For example, variations in inductance and capacitance with temperature can be minimized by special design of inductors and capacitors. See OSCILLATOR.

FREQUENCY SWING. In a frequency-modulated wave, the positive difference between the maximum or minimum frequencies of the frequency-modulated wave and the carrier wave. In general practice, the frequency swing is of the order of 150 kc/s and the carrier-wave frequency, 30–50 Mc/s. See CARRIER WAVE, FREQUENCY MODULATION, MODULATED WAVE, PHASE MODULATION.

FULL LOAD. Load resistance which equals the internal resistance of a source of power. In Fig. 54 the condition shown ensures that the maximum power is delivered to the load; thus the load is the full load of the generator. In another sense, full load might mean the maximum load which could be put across a generator without damage. Note that if the mains load "matched" the generator, the mains voltage would vary 2 : 1 between full and no load. See MATCHING.

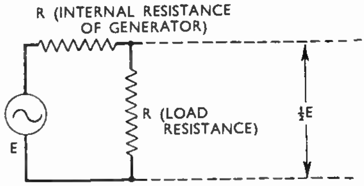


Fig. 54. The full load, considered in terms of power, of a generator is that which matches the internal resistance of the generator.

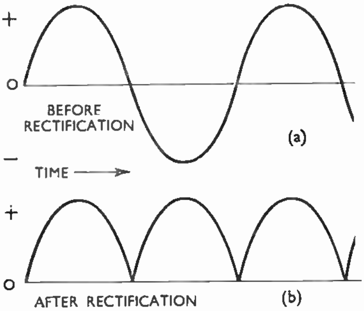


Fig. 55. In full-wave rectification, each half-cycle of the wave is used to produce a unidirectional current; if wave (*a*) is reversed every half-cycle, the wave shown at (*b*) is produced.

FULL-WAVE RECTIFICATION. Method of rectification in which unidirectional current is produced during each half-cycle of the wave rectified. The diagrams of Fig. 55 illustrate the result of full-wave rectification; they should be compared with that illustrating half-wave rectification elsewhere. It should be noted that the same wave form would be obtained if alternate half-cycles of the wave were reversed (see MECHANICAL RECTIFIER).

In full-wave rectification, the lowest

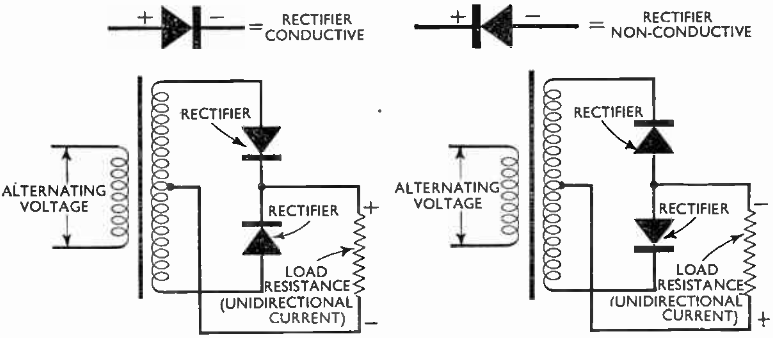


Fig. 56. Basic circuit for full-wave rectification. The rectifier elements are conductive alternately for each half-cycle of the voltage across the transformer secondary, thus the current in the load is always in the same direction.

frequency of the alternating components in the rectified current is twice the frequency of the wave which is rectified.

In half-wave rectification, the lowest frequency of the alternating components in the rectified current is equal to the frequency of the wave which is rectified. See HALF-WAVE RECTIFICATION.

FULL-WAVE RECTIFIER CIRCUIT. Rectifier circuit arranged so that unidirectional current is produced during each half-cycle of the wave rectified. The accompanying diagrams show typical circuits for producing full-wave rectification. In Figs. 56 and 57, as the voltage across one rectifier acts in one direction, it acts in the opposite direction across the other so that only one rectifier is conductive at a time. Each rectifier, however, conducts in the same direction, so that unidirectional current results.

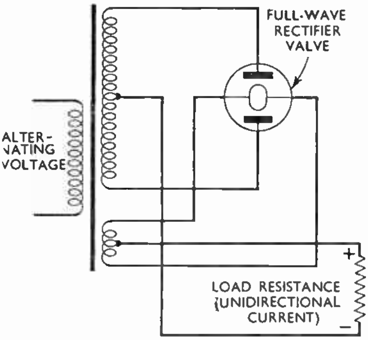


Fig. 57. Connexions of a full-wave rectifier valve. The circuit is fundamentally similar to that of Fig. 56.

The circuit can be looked upon as one in which the two rectifiers act automatically to reverse the circuit path which terminates in the load resistance. It can be compared with the circuit (Fig. 58) of a mechanical rectifier for commutator modulation to show an exact resemblance when modulating and modulated waves have the same frequency. Note that no direct current flows in the secondary of the transformer; this is advantageous because it ensures that the core of the transformer is not permanently magnetized in one or another sense. Bridge connexion of rectifiers is shown in Fig. 59.

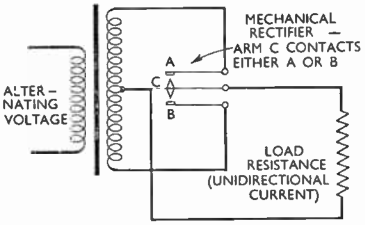


Fig. 58. Circuit of a full-wave mechanical rectifier. Contact *C* closes with *A* or *B* at the instant the alternating voltage is zero, and a unidirectional current flows in the load and in one half or the other of the secondary winding, depending upon which pair of contacts is then closed.

The voltage-doubler is a full-wave rectifier. See FULL-WAVE RECTIFICATION, HALF-WAVE RECTIFICATION, RECTIFICATION, SMOOTHING CIRCUIT.

FULTOGRAPH. System of fascimile transmission and reception. The mod-

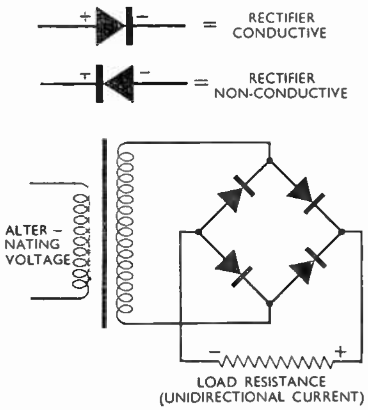


Fig. 59. Bridge connexion of rectifiers which provides full-wave rectification without making use of a transformer with a centre-tapped secondary.

ulation of the transmitted carrier is provided by light variations on a photocell from a spot of light tracing a path over a photograph or drawing. During reception the modulating waves are passed through a damp piece of paper impregnated with an iodine salt. Iodine, released by electrolysis, causes discoloration of the paper, the degree of discoloration being proportional to the intensity of the current; that is to say, it is proportional to depth of modulation of the carrier.

The picture at the sender is mounted on a cylinder which slowly rotates while a spot of light travels along on a track in front of the cylinder. In so doing, it scans the whole picture once in about five minutes. Light reflected from the picture is focused on a photocell and the resultant emission is made to modulate the sender.

At every revolution of the cylinder, a synchronizing impulse is sent out while the rotating mechanism is stopped for a second or so. At the receiver, a stylus is made to trace a path on the impregnated paper, which is wrapped round a similar cylinder. Special electromagnetic relays hold up and release the rotating mechanism at each revolution, in synchronism with the synchronizing impulse.

Thus, the stylus produces a series of lines running round the cylinder, the lines being modulated in accordance with the light and shade of the original picture.

FUNDAMENTAL FREQUENCY. Rate of repetition of a complex wave form. When such a wave form is analysed, it is found to consist of a number of components of which the frequencies are exact multiples of a certain frequency; this frequency is the fundamental frequency. The term may be used also to distinguish the real resonant frequency of a tuned circuit from its harmonics. See FOURIER ANALYSIS, HARMONIC.

FUNDAMENTAL UNITS. Basic units from which a set of derived units is obtained. See DERIVED UNITS.

FUNDAMENTAL WAVELENGTH. Wavelength on which, for example, a sender may be working, in distinction from harmonics thereof. See FUNDAMENTAL FREQUENCY.

FUSE. Protective device for opening a circuit under fault conditions by means of a fuse element which melts when an excessive current flows. The component parts of typical radio types of fuse are shown in Fig. 60 Tinned copper wire is the usual mater-

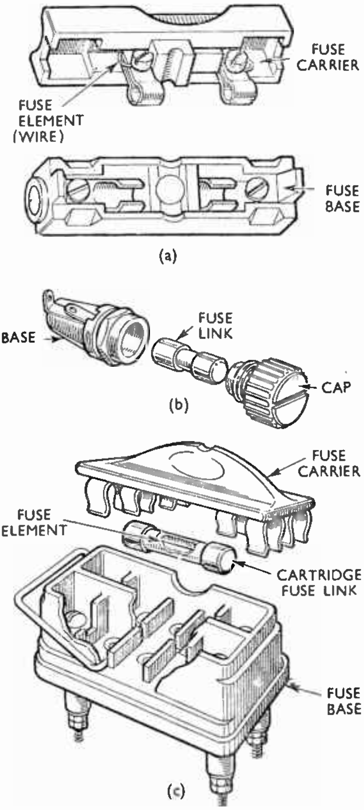


Fig. 60. Three examples of fuses used in radio engineering: (*a*) single-way, rewirable type of fuse; (*b*) single-way, light-duty fuse unit for panel mounting, and (*c*) two-way fuse unit with a cartridge-type fuse link.

ial for the fuse element. For continuous current ratings of 1 amp. or less, the delicate wire is mounted in a ceramic or glass tube fitted at the ends with contact ferrules. This is called a replaceable cartridge-type fuse link. For these low ratings, the fuse element is designed to be melted in less than one second by a current of about 1·7 times the rated value.

For rated currents greater than 1 amp., either cartridge-type fuse links or rewirable fuse carriers may be used. At these ratings, the fuse element melts in less than one second when the current reaches a value of about three times the rated value. Suitable wire-gauges are, for tinned copper wire, (S.W.G.) 38, 35, 29, 25, 23, 22; continuous-current rating (amp.), 3, 5, 10, 15, 20, 25. The other parts of a fuse must be fire-resistant and are usually made of ceramic, asbestos, or mouldings of synthetic resin with an inert mineral filler mixed in. The common types of fuse are suitable for use at voltages up to 250. For higher voltages a longer element is necessary.

FUSE BASE. That part of a fuse to which the fuse carrier is fitted. See FUSE.

FUSE CARRIER. Removable holder which carries one or more fuse links and which may be fitted with contacts for this purpose. See FUSE.

FUSE ELEMENT. Part of a fuse designed to melt and open the circuit when an excessive current flows. See FUSE.

FUSE LINK. That part of a fuse which consists of a fuse element in a cartridge or other container fitted with contacts or capable of being attached to contacts. See FUSE.

G

GAIN. Increase of power or voltage in one part of an electrical system compared with another. Sometimes gain is increase of voltage irrespective of power. The gain (often referred to as the amplification) of an amplifier may be expressed as a number of decibels of voltage or power gain (see DECIBEL). The term "gain control" is preferable to "volume control" in discussing audio output, because the volume of reproduction varies from instant to instant but the mean power can be varied by a gain control. See AMPLIFICATION FACTOR, AUTOMATIC GAIN-CONTROL, STAGE GAIN.

GAIN CONTROL. Process of adjusting the amount of gain given by an amplifier or complete radio receiver, or the device for achieving that end. The need for a means of varying gain is sufficiently obvious when it is remembered that the signal received from a high-power local broadcast sender may be thousands of times stronger than one which has travelled some hundreds of miles to the receiver.

The general problem of adjusting gain to meet the needs of the moment is not an entirely simple one. Consider the design of a superheterodyne receiver with one stage of radio-frequency amplification, frequency changer, two intermediate-frequency amplifying stages, triode detector, and transformer-coupled pentode output valve. Such a receiver as this would overload the final valve severely on many transmissions, and it might seem that the proper place to attenuate the over-strong signal would be between the detector and the output stage.

If this were done, however, signs of overloading might still be heard on any very strong signal, and investigation would show that an excessive input was reaching the detector, or even the second intermediate-frequency amplifying valve (see OVERLOAD). The designer might then turn to the other end of the circuit and provide a means of varying the aerial coupling, thus enabling the input to the first valve to be so controlled as to keep the signal within bounds.

Such a gain control would certainly tend to prevent overloading at any point in the receiver, but still falls short of the ideal. In particular, it is

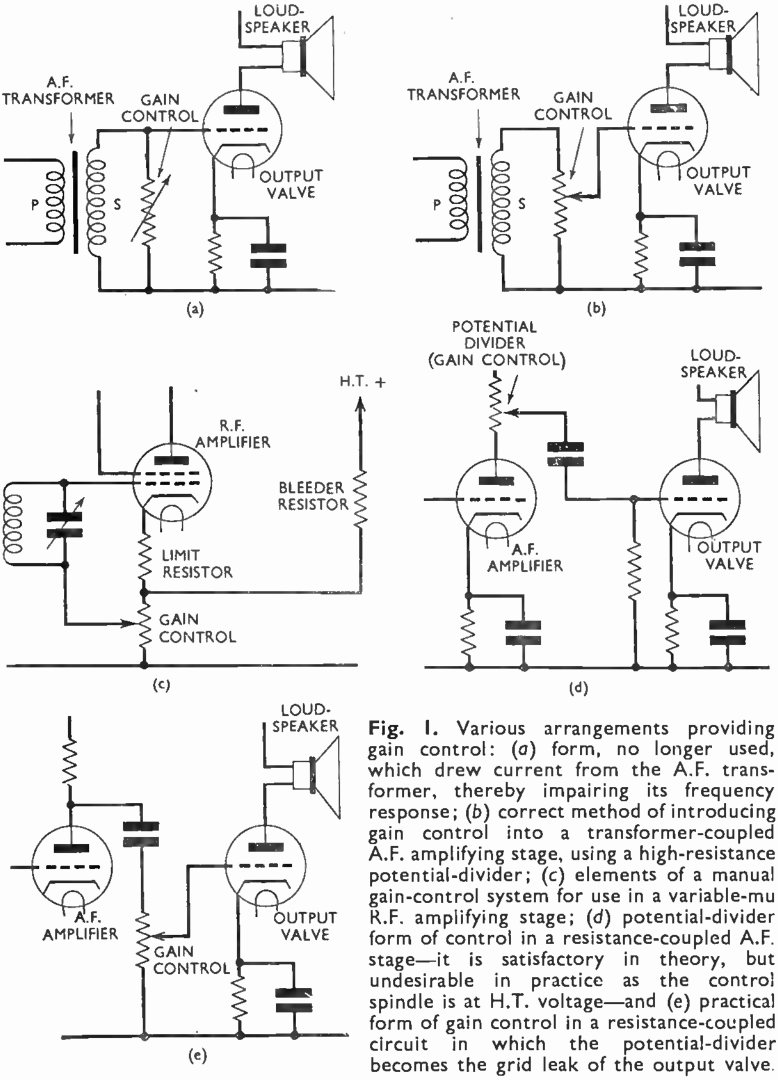


Fig. 1. Various arrangements providing gain control: (*a*) form, no longer used, which drew current from the A.F. transformer, thereby impairing its frequency response; (*b*) correct method of introducing gain control into a transformer-coupled A.F. amplifying stage, using a high-resistance potential-divider; (*c*) elements of a manual gain-control system for use in a variable-mu R.F. amplifying stage; (*d*) potential-divider form of control in a resistance-coupled A.F. stage—it is satisfactory in theory, but undesirable in practice as the control spindle is at H.T. voltage—and (e) practical form of gain control in a resistance-coupled circuit in which the potential-divider becomes the grid leak of the output valve.

objectionable in leaving the actual gain of the amplifying stages at maximum, since it acts merely by reducing the input to them when an over-strong signal is received. Consequently, valve noise, mains noise or circuit noise will still be at maximum (see RANDOM NOISE).

To obtain as quiet a background as possible, it is evidently desirable to reduce the actual gain of the amplifying stages on strong signals. Moreover, the attenuation must be so applied and so combined with correct design of the inherent gain of each amplifying stage that no valve tends to overload much ahead of the rest.

Thus, if the output valve overloads when its grid is swung more than 25 volts, and the preceding stage gives a gain of 10, then the latter valve must itself be capable of accepting an input of at least 2·5 volts (25 divided by the stage gain) if it is not to overload before the output valve does so.

In general, it is good design to see that each valve will accept a little more than is necessary to ensure that the *succeeding* valve is fully loaded. In a receiver thus designed, it is safe to insert the gain-control device at an early point in the circuit, since one can be sure that no other stage will overload if the signal strength is kept within the limits that the output valve can accept.

However, a little further consideration will show that, in a superheterodyne receiver such as that described, the first amplifying stage is not, in fact, the best place to control the overall gain. It happens that random noise is more apt to originate in the intermediate-frequency amplifying stages than in the radio-frequency stage, and it pays to reduce the I.F. gain when a strong signal permits.

Mains hum, on the other hand, is more likely to originate in the low-frequency amplifying circuits; there is, therefore, a case for applying at least some part of the gain-control process at this point.

The designer is indeed led to wonder whether he should not provide a simultaneous gain-control effect in both intermediate and low-frequency amplifying circuits. At one time this was done in some elaborate broadcast receivers, but the general adoption of automatic gain-control has involved some revision of ideas.

The basic method now largely used is to depend on the automatic gain-control to prevent overloading on even the strongest signals, and to provide, in addition, means of adjusting the receiver output to the level desired by the listener (see AUTOMATIC GAIN-CONTROL). This manual gain control frequently operates on the low-frequency amplifying stage, but may also take the form of an over-riding control on the A.G.C. system.

In a receiver designed on these principles, matters will usually be so adjusted that, while the A.G.C. prevents overloading, it does permit the output valve to be fully loaded on all the stronger transmissions. The receiver thus tends to give its maximum output at all times unless the manual gain control is operated.

In T.R.F., or "straight," receiver circuits it is scarcely possible to provide automatic gain-control that is sufficiently effective to prevent overloading on any possible signal. Hence, even if A.G.C. is included, the manual control must usually receive a fair amount of manipulation. Thus, in the "straight" combination of radio-frequency amplifying stage, detector and low-frequency stage, it is usual to control gain by varying the amplification of the R.F. stage.

Turning to the details of gain-control methods, it is found that they fall into two main classes. In the first, some device is used which enables an adjustable fraction of the output of one valve to be passed on to the succeeding one. In the second, the actual magnifying power of the valve itself is varied.

The former of the two general methods is mostly used in low-frequency amplifying circuits, while the second applies principally to radio-frequency amplifiers in which variable-mu valves are largely employed Briefly, these valves, in giving an amount of amplification that can be varied by an alteration of grid-bias voltage, provide a simple method of gain control, either automatic or manual.

In low-frequency amplifying circuits, on the other hand, it is usual to fit some form of potential divider to control the amount of signal voltage passed from one valve to the next. A more detailed conception of these devices may be obtained from a study of Fig. 1. See AMPLIFICATION, SUPERHETERODYNE RECEIVER.

GAIN LIMITER. Device or circuit arranged to fix an upper limit of predetermined value to the gain given by an amplifier. It may be used to minimize the effects of strongly peaked interfering impulses, such as atmospherics, so that they shall not greatly exceed some desired signal in final amplitude. See LIMITER.

GALENA DETECTOR. See CRYSTAL DETECTOR.

GALVANOMETER. Instrument for the detection of small electric currents. The scale of the instrument is usually calibrated in arbitrary units.

GAMMA RAYS. Paths followed by short wave forms of highly penetrating character and emitted by radio-active substances during disintegration Gamma rays are in the X-ray band.

GANGED CAPACITOR. Assembly of two or more variable capacitors on a common spindle, a single control knob then serving to adjust all the capacitors simultaneously (see VARIABLE CAPACITOR).

Since the various sections of such multiple capacitors may be in successive stages of a receiver circuit, they are constructed with careful screening between them, as shown in Fig. 2, and, of course, are accurately matched in capacitance. Combined with each variable section, there is usually incorporated a small trimmer for use in balancing differences in stray capacitances in the ganged circuits.

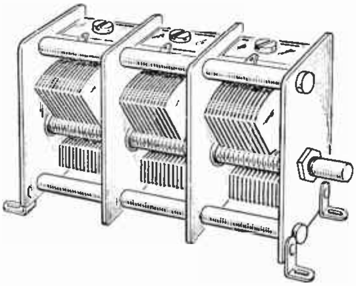


Fig. 2. Example of a three-section ganged capacitor with trimmers

GANGED CIRCUITS. Two or more circuits arranged for tuning by means of a ganged capacitor or other device for simultaneous adjustment of all circuits from a single control. See GANGING.

GANGED CONDENSER. Synonym for GANGED CAPACITOR.

GANGED SWITCH. Multi-pole (and often multi-way) switch, usually of the rotary type. See SWITCH.

GANGING. Arrangement of two or more circuits for simultaneous tuning by capacitors linked on a common spindle or other device permitting adjustment of the whole system from a single tuning knob.

Such tuning is considered essential in broadcast receivers: hence their circuits must be ganged, and considerable research has been devoted to the numerous and interesting problems of maintaining "alignment" (exact identity of tuning on all wavelengths) between the separate circuits of such a system.

The first essential is that all circuits must contain the same amount of inductance if they are to tune similarly The inductors for a chain of ganged circuits must, therefore, be matched in value within close limits.

There are many ways of producing them in matched sets; perhaps the simplest is to wind the units to a fixed specification with all reasonable care, then measure the inductance of each, and group them together in batches according to their divergence from the standard figure.

In this way, the inductors in each group can be used to make up matched sets of units, since those within each group will be of sufficiently equal inductance, though the groups will differ slightly from each other, and from the nominal standard value for the particular receiver design. With careful manufacture to a rigid specification, the variations will be slight; but, if they are allowed to exceed a certain small value, they cause difficulties in fitting a standard wavelength-calibrated dial to the finished receiver.

To ensure the highest accuracy of calibration in the completed receiver, the inductor units must obviously conform to a standard value. To achieve this, a proportion of the output of the winding shops will require a slight final adjustment of inductance. This can be done in a variety of ways, such as a small alteration in the spacing of a few turns in the winding, a change in the position of an iron-dust core or in the extent of a gap therein, or a bodily movement of the inductor unit nearer to or farther from some part of its screening case.

Given a set of closely matched inductors, the problem of ganging is half solved—but only half. There still remain sundry minor but awkward questions, such as the variation in stray capacitance between one circuit and another, the different effect on the tuning of a circuit which results from connecting different types of valves across it, the problem of coupling the aerial to the first circuit without altering its tuning characteristics unduly, and the design of the ganged capacitor itself.

Fortunately, most of the small tuning discrepancies between circuits containing matched inductors can be regarded as due to differences in a certain fixed value of stray capacitance, as though there were a small fixed capacitor across each circuit in addition to the tuning capacitor, these fixed capacitors differing slightly from each other in value.

The total stray capacitance in each circuit must obviously be equalized before a ganged capacitor can be expected to tune a row of circuits accurately, and, for this purpose, small adjustable capacitors called trimmers are used. A trimmer is usually built into each variable section of a ganged capacitor and, in the initial adjustment of a new receiver, these are carefully set to equalize conditions in the ganged circuits.

The aerial connexion to a ganged receiver is chiefly a matter of seeing that it is not coupled too closely to the first tuned circuit. Were it connected directly, for example, the effect would be much as though a fixed capacitor of considerable value had been shunted across the circuit, a capacitor of value so large, in fact, that the trimmers would no longer be able to correct the tuning.

It is usual, therefore, in ganged receivers, to provide either a small untuned coupling inductor for the aerial, with magnetic coupling to the first tuned circuit, or else to connect the aerial to a tapping point on the first inductor so that once again the coupling is comparatively weak. (This arrangement is favoured for selectivity reasons, in addition to the one just given.)

So far as the ganged tuning circuits are concerned, the requirements in the associated multiple capacitor are simple: it must provide the same capacitance in each circuit at any given point in the tuning range, and it must not introduce stray coupling effects between the circuits. To these ends it must be rigidly built, must have good bearings for the rotary spindle, and the sections must be screened from each other.

To enable the individual sections of a ganged capacitor to be matched to the capacitance of their neighbours at all points in the range of adjustment, a number of methods is available. A common and effective one employs a special vane, or plate, on the end of the moving portion of each section. This vane is cut radially so that a number of small segments results as shown in Fig. 3. Each of these segments can be bent to increase or decrease the air-gap between the special moving vane and its opposite number among the fixed ones. The capacitance of the section can thus be adjusted over each small range of travel of the moving vanes.

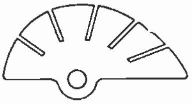


Fig. 3. End moving vane of a ganged capacitor cut into segments for capacitance matching.

Superheterodyne receivers afford an interesting problem in ganging. Here, the requirement is not merely to arrange that a series of circuits shall be tuned simultaneously to the same frequency, but that in the case of one of them a fixed frequency-difference from the rest shall be maintained. This, of course, is the oscillator circuit, which must be kept at the appropriate beat-frequency difference from the signal-frequency circuits.

One method of achieving and maintaining this fixed frequency-difference is by the use of a different value of inductor and specially shaped vanes in one section of the ganged capacitor, possibly combined with a slight off-setting in angular location on the spindle.

In order that the proper frequency-difference, or tracking, shall be preserved when switching from one wave band to another, what are called padding capacitors are used. These are adjustable, rather than variable, capacitors. These are connected in series with the tuning capacitor and may be regarded as reducing the maximum capacitance in the circuit. One padding capacitor is used for each wave band, and they are adjusted to give correct alignment of the oscillator circuit with the others. See STRAY CAPACITANCE, SUPERHETERODYNE RECEPTION, VARIABLE CAPACITOR.

GANGING OSCILLATOR. Oscillator specially designed for testing ganged circuits. It has constant output, but its frequency can be rapidly varied.

GAS AMPLIFICATION. Increase in sensitivity of a gas-filled photocell compared with a similar cell in which there is a high vacuum. The increase is due to ionization of the gas by electrons released from the photo-sensitive cathode and the consequent multiplication of the number of electrons present. See GAS-AMPLIFICATION FACTOR.

GAS-AMPLIFICATION FACTOR. Increase, expressed as a number, in the sensitivity of a gas-filled photocell due to ionization of the gas. See GAS AMPLIFICATION.

GAS CURRENT. Current flowing through an ionized gas; it is carried by positively charged ions. See IONIZATION, IONIZATION CURRENT, IONIZATION POTENTIAL.

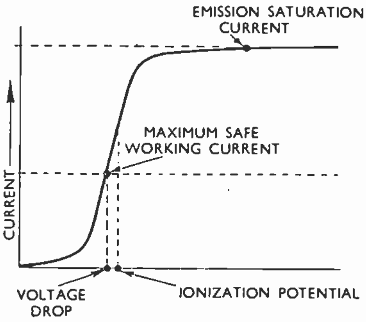


Fig. 4. Graph relating the various quantities associated with a gas-filled diode. The ionization potential is the minimum potential sufficient to set up the process of ionization; the voltage drop is the voltage acting between anode and cathode when the valve is taking its full rated current.

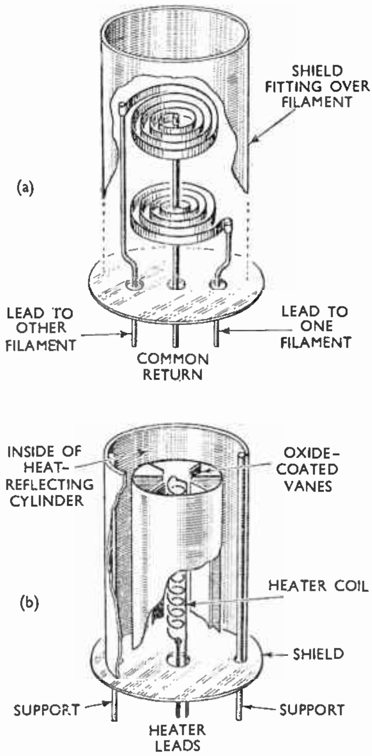


Fig. 5. Owing to annulment of the space charge, the cathode of a gas-filled diode is very different in construction from that of a hard-vacuum valve: (*a*) is a filament type of cathode, and (*b*) is an indirectly heated cathode.

GAS-DISCHARGE TUBE. Synonym for GLOW-TUBE.

GAS-DISCHARGE VALVE. Synonym for GAS-FILLED VALVE.

GAS-FILLED DIODE. Diode in which the amount of gas is sufficient to determine entirely the electrical characteristics of the valve. A gas-filled diode is also termed a gas-filled rectifier (see MERCURY-VAPOUR RECTIFIER). The gas-filled diode differs from the hard-vacuum diode in that, when the gas is ionized, the anode current suddenly changes to a high value which cannot be substantially increased by increasing the anode voltage (see DIODE, EMISSION LIMITATION). Fig. 4 shows the anode-volts/anode-current characteristic of a gas-filled diode.

The anode to cathode potential sufficient to produce ionization is called the ionization potential. The voltage acting between anode and cathode when ionization has taken place is called the voltage drop. Although the anode current can reach its emission-limitation value, it is unsafe to allow it to exceed about a third of this value (Fig. 4). An excessive current causes the cathode to be bombarded by positive ions which destroy it. With mercury-vapour gas, and a typical cathode structure using a separate heater, the voltage drop must not exceed about 22 volts, otherwise the cathode is destroyed.

The anode current of a gas-filled diode is not limited by space charge, and cathodes can be designed to produce the maximum possible emission for a given heating power. The cathode structures (Fig. 5) are quite different from those used in hard-vacuum valves.

The distribution of potential through the gas is shown in Fig. 6. It is seen to be non-uniform. In most of the space between anode and cathode there

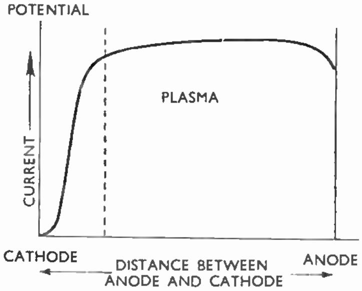


Fig. 6. Distribution of potential in a gas-filled diode. The region of plasma, in which there is an excess of positive ions, is at a higher positive potential than is the anode.

is a surplus of positive ions. This region is called plasma. Electrons strike the edge of the plasma, cause ionization, and then drift through the plasma to the anode. Note that the plasma potential is slightly higher than the anode because of the excess of positive ions.

Mercury vapour, in equilibrium with liquid mercury, is commonly used in gas-filled diodes (see MERCURY-VAPOUR RECTIFIER). Temperature has a considerable effect upon the performance of the valve, and precautions must be taken to maintain the correct temperature.

See CATHODE, DIODE, EMISSION LIMITATION, GAS-FILLED TRIODE, IONIZATION.

GAS-FILLED RECTIFIER. Gas-filled valve used as a rectifier. The fact that the space charge is virtually eliminated in a gas-filled rectifier makes it efficient. The advantage of the low internal resistance of the gas-filled rectifier is not, however, given without attendant disadvantages, notably a liability to damage by misuse.

Where conditions of operation can be stabilized, where short-circuits are not liable to occur in the load circuit and when power-efficiency is a prime requirement, the gas-filled rectifier has a wide range of practical uses. For ordinary mains units, as employed in radio receivers and for small amplifiers, the vacuum-valve rectifier is almost always used (see VACUUM-VALVE RECTIFIER).

Mercury vapour is most often used as the gas in the gas-filled rectifier and, while glow-tubes contain other forms of gas and can be used as rectifiers, they are not generally employed as such. The practical applications of the mercury-vapour gas-filled rectifier are as numerous as the nomenclature distinguishing the variations of a basic principle is confusing.

We must, however, distinguish between the mercury-arc rectifier and the mercury-vapour (hot-cathode) rectifier because there is a basic point of difference, namely, that in the former almost any amount of current may be drawn from the device for a short period, while, in the latter, irreparable damage would be caused by short-circuit or overload. There is a further distinction between these gas-filled rectifiers, inasmuch as some may be designed with electrodes to control the flow of current and others without any electrodes other than anode and cathode. The action of the grid in a gas-filled rectifier is to alter the anode voltage at which the gas becomes suddenly conductive. See IGNITRON, MERCURY-ARC RECTIFIER, MERCURY-VAPOUR (HOT-CATHODE) RECTIFIER.

GAS-FILLED RELAY. See GAS-FILLED TRIODE, GAS-FILLED VALVE.

GAS-FILLED TETRODE. Tetrode in which the amount of gas is sufficient to determine entirely the electrical characteristics of the valve when ionization takes place. The gas-filled triode has the disadvantage, for certain circuit applications, that the control-grid current is large and therefore the control-grid slope-resistance small.

The addition of another electrode between control grid and anode reduces the control-grid current to a very small amount. Thus a gas-filled tetrode can be made to "trigger," or suddenly pass, a large current, by the application of a few microvolts to the grid. Such delicacy of action would be impossible using a gas-filled triode. Fig. 7 compares the electrode structure of gas-filled triodes and tetrodes. See GAS-FILLED TRIODE.

GAS-FILLED TRIODE. Triode in which the amount of gas is sufficient to determine entirely the electrical characteristics of the valve when ionization takes place. A gas-filled diode becomes conductive directly the anode voltage equals the ionization potential. In a gas-filled triode the control-grid potential determines the anode voltage at which ionization takes place; thus the more negative the control grid with respect to cathode, the higher must be the anode voltage, before ionization takes place (see CONTROL RATIO). As in a hard valve, it is the grid potential which determines the potential gradient at the cathode and it is, therefore, in a gas-filled valve, the grid potential which determines the ionization potential.

Once ionization takes place, the control-grid potential makes no difference to the anode current. Thus, before the valve can again become non-conductive, the anode voltage must be reduced well below the ionization potential and maintained at this low value for a fraction of a second (see DE-IONIZATION TIME). Once ionization has ceased, the anode potential may again be raised and the control of ionization potential by grid potential is restored.

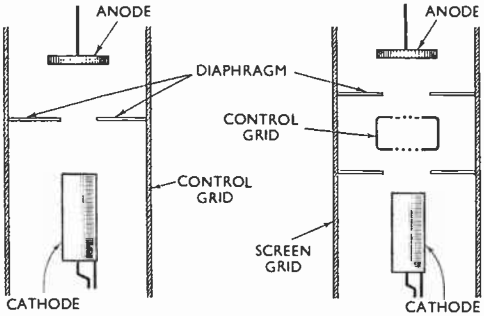


Fig. 7. Diagrammatic representation of the electrode structures of (*left*) a gas-filled triode and (*right*) a gas-filled tetrode. The cathode in each is similar to that employed in a gas-filled diode.

The control-grid current in a gas-filled valve may flow in either direction; thus positive ions forced from anode towards cathode may cause the control grid to become positive, or a collection of electrons may cause it to become negative.

The electrode structure of a gas-filled triode or tetrode is very different from that of a hard-vacuum valve; this is shown in Fig. 7. See GAS-FILLED DIODE, GAS-FILLED TETRODE, GRID CURRENT, IONIZATION, IONIZATION CURRENT, IONIZATION POTENTIAL.

GAS-FILLED TUBE. See GAS-FILLED VALVE, GLOW-TUBE.

GAS-FILLED VALVE. Valve in which the amount of gas is sufficient to determine entirely the electrical characteristics of the valve when ionization takes place. The gas-filled valve differs from the glow-tube because the valve has a hot cathode which emits electrons; the cathode of a glow-tube is cold and does not emit primary electrons (see GLOW-TUBE). Thus the ionization potential of a gas-filled valve is lower than that of a glow-tube (see IONIZATION POTENTIAL).

The basic characteristic of a gas-filled valve is that it has only two electrical conditions: one when it is relatively non-conductive, the other when it is fully conductive. The conduction between anode and cathode is through an ionized gas. Once the gas is ionized, the current that it carries is substantially independent of the voltage acting across it; thus, once the anode-to-cathode potential of a gas-filled diode exceeds a certain value, the anode current leaps up to a high value, and it stays at that value even though the anode voltage be considerably increased.

In a gas-filled triode or tetrode it is the control-grid potential that determines the ionization potential at which ionization takes place, but once the valve becomes conductive, the grid has no more control over the anode current.

The hard-vacuum valve is distinguished by its property of giving a nearly linear relationship between, for instance, anode volts and anode current (when this is not limited by space charge or emission limitation) and a linear relationship over parts of its characteristic between control-grid volts and anode current (see ANODE-VOLTS/ANODE-CURRENT CHARACTERISTIC, GRID-VOLTS/ANODE-CURRENT CHARACTERISTIC).

On the other hand, the gas-filled valve, like a relay, has two conditions, conductive or non-conductive. It is sometimes called a trigger valve, thermionic relay or valve relay because of this property. It has many applications, notably as an efficient rectifier, and in applications similar to those in which electromechanical relays might be used. The fact that the electrons and ions take a definite time to recombine limits the frequency of operation of a gas-filled valve to about 50 kc/s. See DE-IONIZATION TIME, DIODE, GAS-FILLED DIODE, GAS-FILLED TETRODE, GAS-FILLED TRIODE, GLOW-TUBE, IONIZATION, MERCURY-VAPOUR RECTIFIER.

GAS FOCUSING. In a cathode-ray tube, the focusing of the electron beam by means of the ionization of residual gas in the tube. Positive ions are formed by the collision of electrons with the small quantities of gas in the tube, giving rise to a core of positive ions in the beam and thus providing the necessary focusing field.

GAS VALVE. Synonym for GAS-FILLED VALVE.

GAUSS. Unit of magnetic-field density in the centimetre-gramme-second system; it is equal to one magnetic line per square centimetre.

GEE. See NAVIGATIONAL AID.

GENERATOR. See A.C. GENERATOR, D.C. GENERATOR, SYNCHRONOUS GENERATOR.

GETTER. Substance used in the process of degassing a hard-vacuum valve. It is placed in the bulb and made to burn to absorb residual gas. In degassing it is important to remove all gas that may be occluded in the metal of the electrodes or in the glass; degassing is helped by heating these parts while pumping goes on. The getter is an added process; it consists in the quick volatilizing or burning of a substance within the valve.

This necessarily uses up any oxygen present. Magnesium, barium and phosphorus are used as getters. Mixtures may also be used, but the object is always to absorb oxygen by a burning process. It is possible that the explosion caused by the sudden burning of a getter may also trap gases which are not absorbed in the burning process, so that the gases are combined with the hot substances and cannot escape when these cool. See DEGASSING, KEEPER.

GILBERT. Measure of magnetomotive force in the centimetre-gramme-second system. It is equal to $0{\cdot}4\pi$ ampere-turns.

GLOW DISCHARGE. Current passing through a gas at low pressure, and accompanied by the emission of light. An example of glow discharge is sometimes seen in a vacuum valve when high anode voltages are used and the valve is soft, i.e. the vacuum has deteriorated.

GLOW-TUBE. Tube in which the bulb contains gas at a low pressure. Anode current flows through the gas when this is ionized. The glow-tube differs from the gas-filled valve in having a cold cathode; there is thus no source of electrons to start the process of ionization, which is brought about solely by the potential gradient acting on the gas between anode and cathode. The tube will conduct whichever way round the voltage is applied.

In practice, the electrodes may be of different construction; for instance, the cathode may be coiled or sputtered with material of low work-function. For working conditions, one electrode is made positive and called the anode, the other being the (negative) cathode. The voltage at which ionization takes place is the ionization potential, but is also referred to as the striking voltage.

Fig. 8 shows the anode-volts/anode-current characteristic of a glow-tube.

It will be noted that the striking voltage is greater than the voltage drop. The voltage drop in a glow-tube is higher and the current density lower than in a gas-filled valve. The table below shows some characteristics of typical glow-tubes.

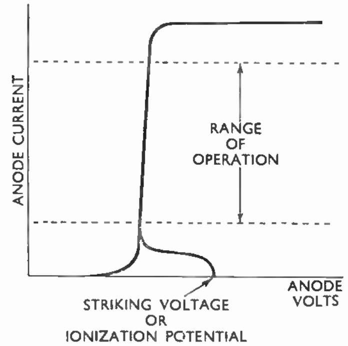


Fig .8. Graph of the anode-volts/anode-current characteristic of a glow-tube. This may readily be compared with that applicable to a gas-filled diode by reference to Fig. 4.

Max. Current (mA)	*Operating Voltage*	*Striking Voltage*
2	48–87	87
30	75	105
50	90	125
60	50–60	85

The last entry refers to a 3-watt neon glow-tube

Glow-tubes are chiefly used to stabilize the output voltage from mains units. This is because the voltage drop is largely independent of the current. The gas, typically neon or argon, is usually at a pressure of 0·1 mm. of mercury. See DIODE, GAS-FILLED DIODE, IONIZATION, IONIZATION POTENTIAL, VOLTAGE DROP.

GLOW-TUBE RECTIFIER. Glow-tube used as a rectifier. The glow-tube can conduct electricity either from cathode to anode or from anode to cathode, and is not inherently a rectifier. Nevertheless, by making the electrodes of different areas, asymmetrical conduction can be produced. The property of the glow-tube, namely, that its voltage-drop is largely independent of the current flowing through it, gives it a wide application as a voltage regulator, but it is seldom, in fact, used as a rectifier. See GLOW-TUBE, NEON GLOW-TUBE.

"GO" CHANNEL. Term distinguishing one conductor of a transmission line from another, or a channel used for one-way communication.

GOLDSCHMIDT ALTERNATOR. Synchronous generator for the production of currents at radio frequencies. See SYNCHRONOUS GENERATOR.

GONIOMETER. Synonym for RADIO-GONIOMETER.

GRAMOPHONE. Machine for rotating a gramophone record, or disc, and reproducing it by means of a sound-box (acoustic) or a pick-up (electrical). The term was invented to distinguish between the phonograph system, which used cylinders, and a machine for playing flat discs. In America, however, the terms phonograph and gramophone are synonymous. See ELECTRICAL RECORDING, GRAMOPHONE PICK-UP, SCRATCH FILTER.

GRAMOPHONE PICK-UP. Reproducing head used for the electrical reproduction of gramophone records or direct-recorded discs. It is usually mounted on an arm pivoted at one corner of the turn-table plate. The pick-up and arm are driven in an arc across a radius of the disc by the pull exerted on the needle in the spiral groove as the turn-table revolves.

The needle traces the wave form of the grooves, setting up e.m.f.s at the terminals of the pick-up. These are amplified and equalized to produce, from the loudspeaker, sound waves corresponding to those applied to the microphone during the recording process.

The *moving-iron* type of pick-up

(Fig. 9) is preferred for general use because of its robustness and simplicity. It works on the principle of electromagnetic induction. A soft-iron armature, situated in a stationary coil, is pivoted at some point so that, as the needle is displaced about its mean position when tracking a groove, the armature oscillates about its pivot. When the armature is in its upright equilibrium position, as in Fig. 9, no lines of force pass along its length; instead the lines cross from each of the two north pole-pieces to the opposite south pole-piece.

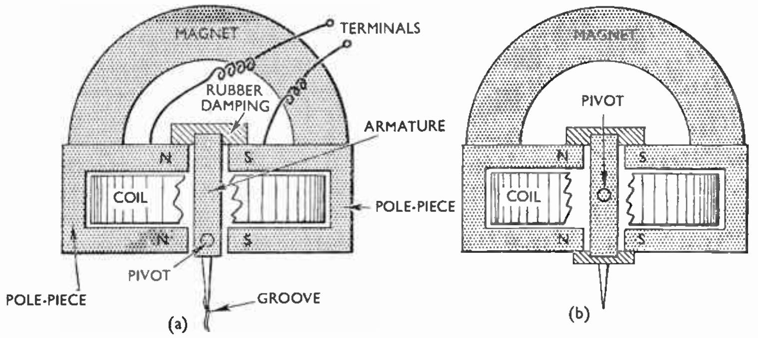


Fig. 9. Diagrams showing operating principles of two forms of gramophone pick-up: (*a*) the unbalanced-armature or half-rocker type, and (*b*) the balanced-armature type, in which the armature is pivoted at or near its centre of gravity.

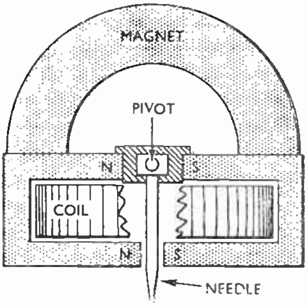


Fig. 10. Needle-armature pick-up. The needle forms the greater part of the armature and is therefore of iron or steel; it may be pivoted for either balanced or unbalanced working.

If, however, the armature rocks in a clockwise direction about its pivot, it provides a low-reluctance path between the lower north and the upper south pole-pieces. Some lines of force leave their original horizontal path to travel upwards along the armature and, in moving, they cut the numerous turns of the coil and generate an e.m.f. at its ends. This e.m.f. is generated only *during the movement* of the armature; there is no output when the armature is stationary.

If the armature oscillates in an anticlockwise direction, it provides a low-reluctance path between the upper north pole-piece and the lower south pole-piece, and lines of force move to take up this path. The lines now move *down* the armature and, in cutting the coil, generate an e.m.f. of opposite polarity to that produced before. Thus an oscillatory movement of the armature gives rise to an alternating e.m.f. at the pick-up terminals, this e.m.f. being directly proportional to the speed of the movement and the number of turns in the coil.

In Fig. 9a the armature is pivoted at one end and is called an unbalanced armature or half-rocker. If pivoted at the centre (Fig. 9b) it is called a balanced armature or full-rocker. If, as in Fig. 10, the needle forms the armature, the pick-up is said to be of the needle-armature type. The working principles of all three types are similar.

The disadvantage of the original moving-iron pick-ups was their inherent resonance. One resonance occurred at the natural mode of armature vibration, the resonant frequency being between 3,000 and 5,000 c/s. At and near this frequency, the e.m.f.s are not proportional to, but considerably greater than, the speed of needle-point movement. A second resonance was prevalent at a lower frequency (50–150 c/s), due to the mass of the head and arm swinging about the pivot of the arm whilst the needle traced the groove. Another fault was the harmonic distortion of the output e.m.f. particularly noticeable at large stylus-displacements. The relationship between armature velocity and output e.m.f. is, in a good design, reasonably linear for small angular displacements of the armature, but departs from linearity if the armature moves very close to the pole-pieces.

In modern moving-iron pick-ups, the treble resonance is minimized by reducing the armature mass, thus tending to raise the resonant frequency to a point beyond the normal audio-frequency range. The effect of bass resonance is reduced by decreasing the stiffness of needle suspension which tends to lower the resonant frequency. Harmonic distortion is decreased by using a wider pole-piece gap.

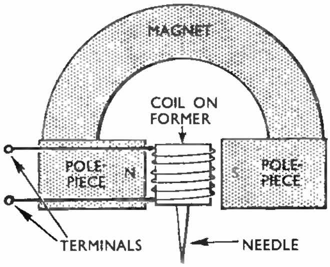


Fig. 11. Theoretical drawing of a moving-coil type of gramophone pick-up. As the needle traces the groove, the coil moves bodily in the gap between the pole-pieces, causing e.m.f.s to be induced in the coil at the frequency of the recorded signal.

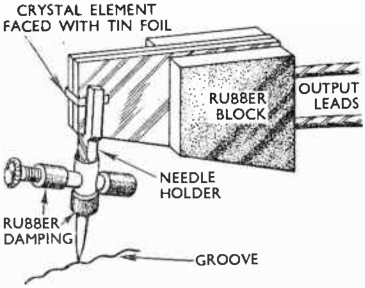


Fig. 12. As the needle of a crystal pick-up traces a groove, the crystal plates are subjected to alternating mechanical stresses; these stresses cause e.m.f.s. to be set up between the two adjacent faces of the element.

In the *moving-coil* type of pick-up (Fig. 11), the needle is attached to a former which carries the coil, the latter oscillating at the frequency of needle vibration. The magnetic field is provided by a permanent magnet and e.m.f.s are generated at the terminals of the coil by virtue of electromagnetic induction.

This type is less prone to resonance than the moving-iron type, but is less sensitive. It requires an intense magnetic field which, in earlier types, necessitated a large magnet. High-density magnets are now employed, reducing the mass of the pick-up and improving its sensitivity. Harmonic distortion is low, largely owing to the absence of iron, at high needle-displacement amplitudes.

The *piezo-electric*, or *crystal*, pick-up works on principles entirely different from those of the moving-iron and moving-coil. If certain crystals are subjected to mechanical stress, e.m.f.s are set up between the facets at which the stress is applied. If two crystal plates are cut from Rochelle salt (sodium-potassium tartrate) they can be so arranged that an applied stress will cause one to expand and the other to contract and electric potentials will be set up between the plates.

In the crystal pick-up (Fig. 12) two such plates are used. A needle-holder is attached to the assembly and, as the needle vibrates, varying pressures are exerted on the crystal plates, setting up alternating e.m.f.s between conducting electrodes touching the crystals. The amplitude of the e.m.f.s is proportional to the amplitude of the groove formation. The crystal pick-up has high sensitivity, is somewhat fragile in construction and subject to mechanical resonance.

The maximum e.m.f.s generated at the terminals of any pick-up rarely exceed 1 volt r.m.s. Excepting the crystal types, modern pick-ups sacrifice sensitivity to achieve a level frequency response. With all types, an amplifier is necessary to produce sufficient energy to operate a loudspeaker.

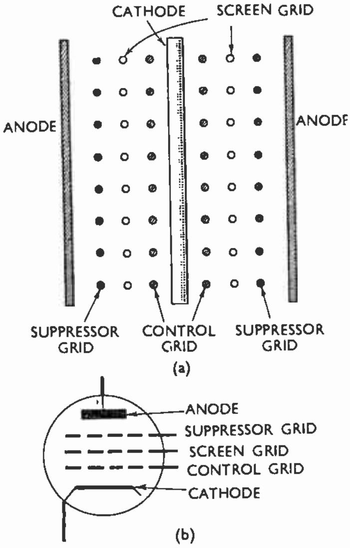


Fig. 13. Diagrams distinguishing grids from the other electrodes of a valve: (*a*) section through, and (*b*) conventional symbol for, a pentode.

The moving-iron and moving-coil types are constant-velocity devices; that is to say, the e.m.f.s produced are proportional to groove velocity. This velocity in r.m.s. values is equal to 4·44 *fa* cm/sec, where *f* is the frequency in cycles per second and *a* the amplitude of displacement, in centimetres, of the wave form.

For reference purposes, a standard velocity of 1 cm/sec at 1,000 c/s is generally adopted. If the velocity of a recording system is 2 cm/sec at 1,000 c/s, then it can be given in decibel form as +6 db. with reference to the standard velocity.

Over most of the frequency range, gramophone records and discs are recorded at approximately constant velocity; hence a constant-velocity pick-up will have generated at its terminals e.m.f.s, the wave form of which will correspond to that of the recorded sounds. Below 250 c/s, however, the groove amplitude is attenuated during recording to avoid groove overlap, and the pick-up must be equalized to restore the level. With some pick-ups, the natural resonance of the mass of pick-up and arm automatically corrects this attenuation. With others, electrical equalization of the amplifier is necessary.

The crystal pick-up is a constant-amplitude device. Thus the e.m.f.s generated at its terminals are proportional to groove amplitude. Since, with constant-velocity recordings, the amplitudes of needle displacement are inversely proportional to frequency, this pick-up has a falling characteristic; that is, the higher notes are attenuated. This can be corrected by incorporating an equalizer in the amplifier. See ELECTRICAL RECORDING, ELECTRICAL REPRODUCTION, PIEZO-ELECTRIC CRYSTAL.

GRAPH. Line drawn with respect to rectangular co-ordinates to illustrate the relationship between two variable quantities. In many cases, the term "characteristic" is used instead of "graph" (see, for example, VALVE CHARACTERISTIC). The word "curve" is also used instead of graph, but is illogical when the graph shows a linear relationship between two quantities and is therefore a straight line. See SINE GRAPH, VALVE CHARACTERISTIC.

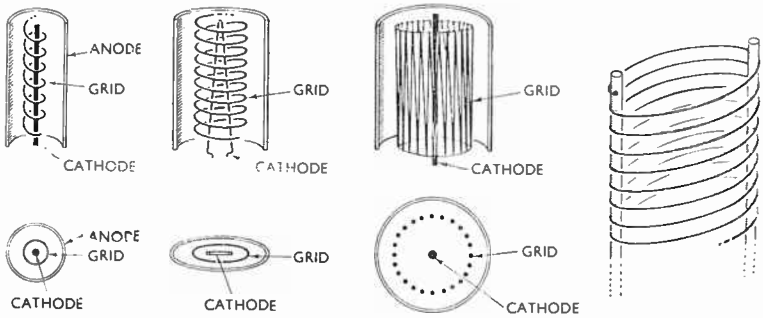


Fig. 14. Various forms of electrode structure, shown in elevation and plan, the control grid being indicated in each case. Also shown (*right*) is the method of mounting the grid; the pillars have notches to take the turns of the coil.

GRAPHICAL SYMBOLS. See SYMBOLS.

GRATZ RECTIFIER. Full-wave rectifying circuit in which four valve rectifiers or four metal rectifiers are connected in the form of a bridge. See BRIDGE NETWORK.

GRID. Electrode of a valve constructed so that some electrons and ions may travel through it and some be collected by it. Electrons and ions accelerated by the potentials acting between electrodes may pass between the coils of a helical electrode, and some may hit the wires forming the helix and so cause current to flow to and from the grid electrode. Grid-type electrodes are used to control the flow of electrons according to their potential, and are also used as shields to reduce the capacitance between electrodes. Grid electrodes are shown in Figs. 13 and 14

The grid-type electrodes are classified as *control* grids, *screen* grids and *suppressor* grids. The control grid is located nearest to the cathode and is normally a helix embracing, but not touching, the cathode; the control-grid potential has the greatest effect in determining the potential gradient at the cathode and hence the space current (see VALVE). The control grid is usually negatively biased with respect to cathode and so reduces the space current; or, in a gas-filled valve, determines the ionization potential.

The function of the screen grid is to act as a shield between control grid and anode, and so reduce the control grid to anode capacitance. It is arranged to embrace the control grid and thus act as a shield. It is biased at a positive potential with respect to cathode. This potential is of the same order as the anode potential. The screen grid necessarily collects some electrons (though most travel to the anode) and so causes a current to flow between the source of screen-grid potential and the screen grid, and so to the cathode (see SCREEN-GRID CURRENT).

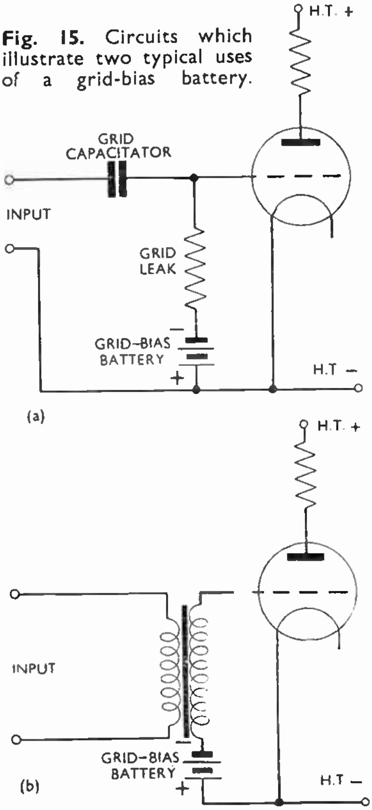
The suppressor grid is placed between anode and screen grid, and is usually, though not invariably, connected to the cathode. Its function is to prevent secondary electrons emitted by the anode from passing to the screen grid (see SECONDARY EMISSION). The great majority of electrons coming from the cathode cannot pass the suppressor grid, since it is at a low (namely, cathode) potential. In frequency-changer valves, other grids are added to form screens between the operative electrodes.

Grids are generally made from a wire helix; but they may be in the form of hollow cylinders, with holes or with plates, mounted parallel to the electron stream. See CONTROL GRID, GRID CURRENT, PENTODE, SCREEN GRID, SCREEN-GRID CURRENT, SUPPRESSOR GRID, TETRODE, TRIODE.

GRID BASE. Synonym for CUT-OFF BIAS.

GRID BIAS. Component of the grid potential which has a steady value. The term generally refers to the control-grid bias; where the screen grid is concerned, the term screen-grid bias is used. See AUTOMATIC GRID-BIAS, BIAS, CATHODE BIAS, GRID-BIAS BATTERY.

Fig. 15. Circuits which illustrate two typical uses of a grid-bias battery.



GRID-BIAS BATTERY. Battery, commonly of dry Leclanché cells, used to maintain a steady difference in potential between the grid and filament of a valve. Two circuits containing a grid-bias battery are shown: Fig. 15a shows a resistance-capacitance-coupled amplifier in which the grid-bias battery is connected to a grid leak; Fig. 15b shows a transformer-coupled amplifier in which the battery is connected to the secondary winding of the transformer. See GRID LEAK.

GRID-BIAS MODULATION. Synonym for GRID MODULATION.

GRID-BIAS RESISTOR. See CATHODE-BIAS RESISTOR, GRID LEAK.

GRID-BIAS VOLTAGE. Synonym for GRID POTENTIAL.

GRID CAPACITOR. Capacitor connected between the control grid of a valve and the associated circuit. The capacitor has an infinite resistance to D.C., but offers only a low impedance to audio- or radio-frequency currents. A GRID LEAK (q.v.) is generally used in conjunction with the capacitor to permit of the grid being supplied with D.C. bias.

GRID CIRCUIT. Any circuit associated with the control grid (not screen grid) of a valve. See CONTROL GRID, GRID.

GRID CONDENSER. Synonym for GRID CAPACITOR.

GRID CONDUCTANCE. Synonym for GRID SLOPE-CONDUCTANCE.

GRID CONTROL. Synonym for GRID MODULATION.

GRID CURRENT. Current flowing to and from the control-grid electrode. If, in a hard-vacuum valve, the grid is made positive with respect to cathode, it collects electrons and grid current flows between control grid and cathode. In a gas-filled triode or tetrode the grid may, depending upon its potential, collect either electrons or positive ions. Thus, in a gas-filled triode, grid current can flow in either direction. The effect can also take place to a lesser degree in a hard-vacuum valve (see GAS-FILLED TRIODE, REVERSE GRID CURRENT).

With small differences of potential between grid and cathode, the grid current is very small, but it increases rapidly as the grid becomes more positive. The anode potential affects grid current; if it is large, it draws electrons away from the space charge and these pass the grid; if it is small, the grid collects more electrons. It is helpful to realize that, when the control grid is positive with respect to cathode, then grid and cathode form a diode; while the anode–cathode structure forms an amplifier of the potentials, due to the current rectified between grid and cathode.

The production of grid current in a hard-vacuum valve, when the grid is positive with respect to cathode, is an important factor in many circuit applications; notably, grid-leak detection, the use of the grid-leak in oscillators, and as the driver stage preceding a class-B valve amplifier. See AMPLIFICATION, DIODE, GRID-CURRENT CHARACTERISTIC, GRID SLOPE-RESISTANCE.

GRID-CURRENT CHARACTERISTIC. Graph plotting grid current against grid volts. In a hard-vacuum valve, the grid-current characteristic resembles that of the anode-volts/anode-current characteristic of a hard-vacuum diode, but is modified by the anode potential. See GRID CURRENT, REVERSED GRID CURRENT.

GRID-CURRENT MODULATION. Synonym for GRID MODULATION.

GRID DETECTION. Process wherein detection is performed by the grid and cathode of a triode or multi-electrode valve. A typical circuit is shown in Fig. 16. In the absence of any signals, the grid will take up a potential such that a very small grid current flows. On the application of a positive signal, the grid will momentarily become positive and grid current will flow. It will flow into the capacitor, which will thus become negatively charged. As a result, the anode current of the valve will be decreased.

The action is similar to that of the diode detector, the circuit, in fact, being equivalent to that of Fig. 18, on page 162, under DIODE DETECTOR. The grid and cathode act as the diode and the same conditions regarding the time constant of the resistance-capacitance combination apply. The grid capacitance cannot be made too small because the voltage actually applied between grid and cathode is not the full input voltage, but only a portion thereof, and is determined by the ratio of the input impedance of the valve and the reactance of the capacitor.

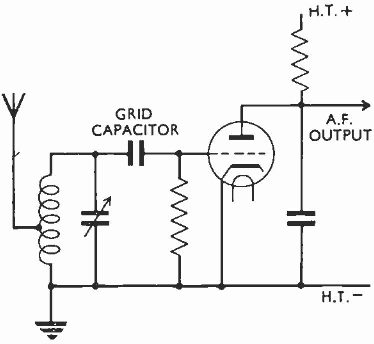


Fig. 16. Circuit for grid detection by the use of a triode; the detection process is explained in the text.

The desirable condition, of course, is that the reactance of the grid capacitor should be small compared with the valve impedance, so that nearly all the input voltage reaches the valve. If the grid capacitor is made too small its reactance becomes high and an appreciable fraction of the voltage is lost.

Given proper conditions, however, the grid potential will vary in accordance with the modulation changes and, consequently, the anode current will also vary. The arrangement thus combines the action of detector and amplifier in one valve. The valve will also tend to amplify the radio-frequency carrier—which we do not require.

To avoid this, and also to by-pass the carrier as quickly as possible after this has been finished with, it is customary to connect from anode to cathode a capacitor of such a value that it does not seriously reduce the amplification of the valve at the upper audio frequencies of the modulation, but acts as a low-impedance by-pass to the very much higher carrier frequency.

For weak signals, the valve operates with a small negative grid voltage. Under these conditions, the slope of the anode-current/grid-voltage characteristic is high, and good amplification is obtained. The valve will, in fact, always work just above the point at which grid current commences, which is the condition for maximum amplification. As the strength of signal increases, however, the increasing negative charge on the grid capacitor moves the working point on the valve characteristic towards the bottom, where it is becoming increasingly more curved, so that the amplification falls off, and distortion occurs.

If the operating point reaches the bottom bend of the curve, anode-bend rectification will commence. But, with anode rectification, the anode current increases when the signal arrives, which is just the opposite of the conditions with grid rectification. Hence the two effects are in opposition and the detector efficiency falls rapidly and may even become zero. The grid detector is thus most suitable for weak signals. It can be used with strong signals if a high anode voltage is used (see POWER DETECTION) but, in any case, the signal which the circuit can accept is always limited.

GRID DISSIPATION. Heat dissipated in a grid electrode. Although, in the majority of circumstances, the anode has to dissipate the greatest heat, a screen grid may also become very hot when drawing considerable current. As its structure does not lend itself so readily to heat dissipation, the question of overheating of the screen-grid electrode, or the control grid of a gas-filled triode, is one that must be considered when considerable power is handled. See ANODE DISSIPATION, COOLED VALVE, ELECTRODE DISSIPATION.

GRID EMISSION. Emission of secondary electrons from a grid electrode. See SECONDARY EMISSION.

GRID GLOW-TUBE. Glow-tube in which a grid regulates initiation of the discharge.

GRID IMPEDANCE. Impedance of the control-grid electrode. See ELECTRODE IMPEDANCE.

GRID KEYING. In radio telegraphy, the keying of the sender by changing the grid bias on one of its valves.

GRID LEAK. High-value resistor connected between the grid of a valve and a point of steady potential, such as an earth connexion or a GRID-BIAS BATTERY (q.v.), when there is a capacitor in the grid circuit. Without a grid leak or some other conducting path from the grid, electrons would accumulate on the grid, causing the anode current to fall to zero and the valve to become inoperative. This is prevented by the grid leak, which provides a path, that is, a leak for the electrons on the grid.

GRID MODULATION. Modulation in which the grid potential of a valve is varied by both the carrier and modulating waves. The term is used to distinguish grid from anode modulation; the former being a non-linear and the latter a linear form of modulation. See NON-LINEAR MODULATION, GRID MODULATOR.

GRID MODULATOR. Non-linear modulator in which the sources of the carrier and modulating waves are connected in series in the grid-cathode circuit of a valve. A filter in the anode circuit of the valve selects the modulated wave. Fig. 17 shows the schematic of a grid modulator, and the resulting wave forms. The valve is operated at a bias greater than cut-off and, when the modulating wave has its maximum positive amplitude, class-B operation is obtained. For all other values of the amplitude of the modulating wave, the valve operates under class-C conditions. If some degree of modulation distortion is tolerable, the grid may be allowed to become more positive than the cathode, thus increasing efficiency. See GRID MODULATION, MODULATION DISTORTION, NON-LINEAR MODULATION.

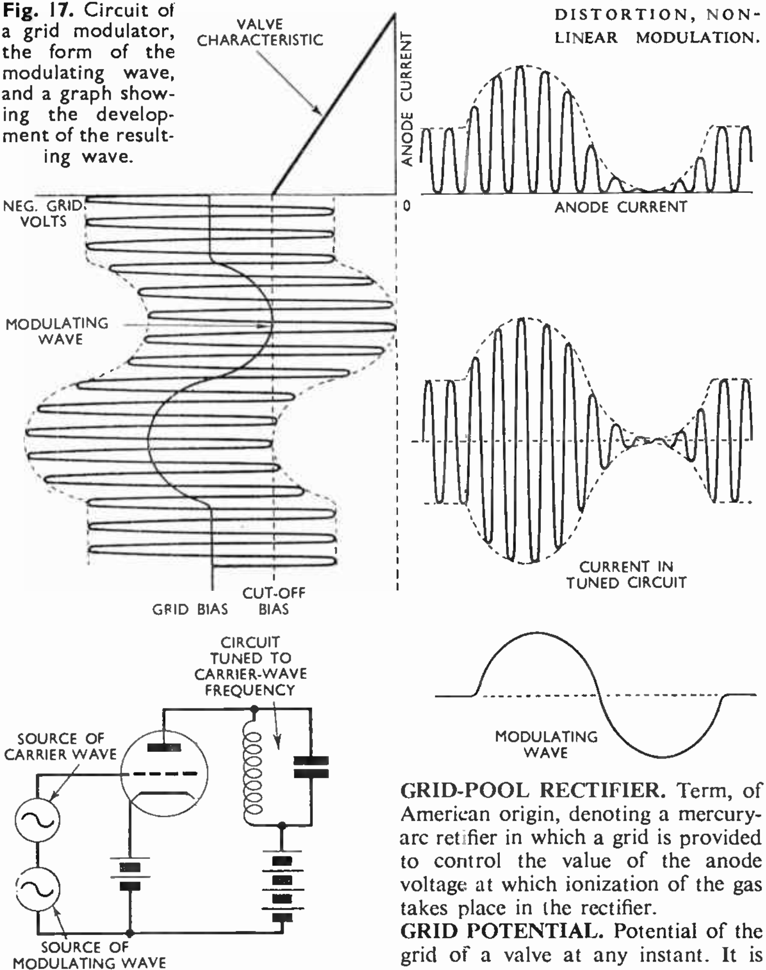


Fig. 17. Circuit of a grid modulator, the form of the modulating wave, and a graph showing the development of the resulting wave.

GRID-POOL RECTIFIER. Term, of American origin, denoting a mercury-arc rectifier in which a grid is provided to control the value of the anode voltage at which ionization of the gas takes place in the rectifier.

GRID POTENTIAL. Potential of the grid of a valve at any instant. It is usually given with respect to the cathode. See GRID BIAS.

GRID RECTIFICATION. See GRID DETECTION.

GRID RESISTANCE. Deprecated synonym for GRID SLOPE-RESISTANCE.

GRID SLOPE-CONDUCTANCE. Inverse of GRID SLOPE-RESISTANCE.

GRID SLOPE-RESISTANCE. Slope resistance of the control grid. This is finite only when grid current flows. See CONTROL GRID, GRID CURRENT, SLOPE RESISTANCE.

GRID-STOPPER. Synonym for PARASITIC STOPPER.

GRID SWEEP. Difference between the extreme limits of the grid potential of a valve used as an amplifier (Fig. 18). It is obvious that, if the excursions of grid potential either reduce the grid potential below the cut-off value, or make it positive with respect to cathode, distortion of the output wave is liable to occur. The term "available grid sweep" is used to mean the total excursion of grid volts over which the grid-volts/anode-current dynamic characteristic of the valve is substantially linear. See AMPLIFIER, CLASS-A, CLASS-B AND CLASS-C VALVE OPERATION.

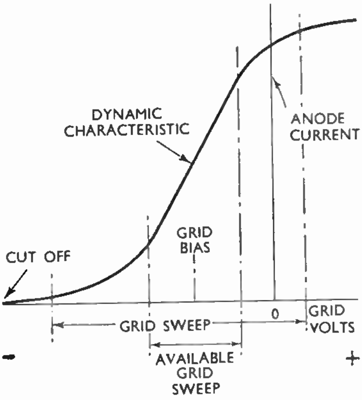


Fig. 18. Diagram showing that the grid sweep is the total excursion of grid volts; the available grid sweep is that portion of it over which the grid-volts/anode-current characteristic of the valve is substantially linear.

GRID SWING. Synonym for GRID SWEEP.

GRID VOLTAGE. Term commonly used for GRID POTENTIAL.

GRID-VOLTS/ANODE-CURRENT CHARACTERISTIC. Graph of the voltage of the control grid plotted against the resulting anode current. Fig. 19 shows the typical grid-volts/anode-current characteristics of a triode. For any one curve the anode voltage is constant; and its value determines the position of the curve. The slope of the curve at any point gives the mutual conductance of the valve at that point. Mutual conductance should be defined with respect to grid and anode volts. When a tetrode or pentode characteristic is shown, the value of the screen-grid bias is also given because the position of the curve is also affected by this. See ANODE-VOLTS/ANODE-CURRENT CHARACTERISTIC, GRID SWEEP, MUTUAL CONDUCTANCE.

GROUND. Synonym used in America for EARTH.

GROUNDED-GRID AMPLIFIER. Triode amplifier of radio-frequency waves in which the control grid is earthed and the input wave is applied between cathode and earth and thus

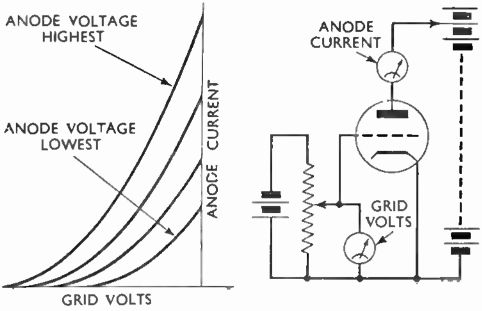


Fig. 19. Grid-volts/anode-current characteristics of a valve at four fixed values of anode voltage. The circuit diagram indicates how the values are taken, the anode voltage being kept constant for plotting each graph.

varies the potential of the cathode. The circuit, shown in Fig. 20, has the advantage over the more conventional arrangement that little, if any, neutralization is necessary. A conventional triode amplifier cannot be used for amplification of waves whose frequency is greater than about 100 kc/s because the anode-control grid capacitance causes positive feedback and consequent oscillation. This can be overcome by neutralization, or by the adoption of the grounded-grid amplifier arrangement. In the latter, the grid acts as a screen between anode and cathode and helps to prevent feedback via anode-cathode capacitance. The grounded-grid amplifier is also known as the inverted amplifier.

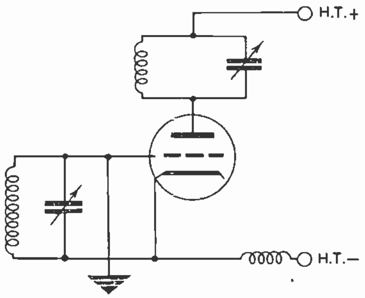


Fig. 20. Grounded-grid amplifier, sometimes known as an inverted amplifier; the input is applied between the cathode and earth.

GROUND-PATH ERROR. That component of the total error of a direction-finding system which is due to lateral deviation of waves that travel over the surface of the earth, in distinction from errors due to lateral or other deviation of those which come by reflection from the ionosphere.

GROUND RAY. Radio ray which travels to the receiver over the surface of the earth and is not reflected by the ionosphere. At low frequencies, it is usual to speak of the ground wave, but at the higher frequencies, where the wavelength is small compared with the distance travelled, it is permissible to think of radio rays as if they were optical rays; but it must be remembered that the rays have no separate existence and are simply representative of an indefinite number of possible paths.

As the distance from the sender increases, the ground ray gets weaker, the actual strength depending upon the frequency in use and the nature of the intervening terrain. For example, a station having a ground range of, say, 1,000 miles over sea water would have a range of only about 100 miles over desert sand.

Moreover, the lower the frequency in use, the greater is the ground range. This is because diffraction effects in the lower atmosphere cause a tilting of the wave front downwards, a process which tends to make the wave follow the surface of the earth. The tilting increases with the frequency, which accounts for the rapid disappearance of the ground ray at high frequencies. With low and medium frequencies, the range of the ground ray may be increased by increasing the power radiated, but, because of diffraction effects at high frequencies, an increased ground-ray range is not evident.

Ground rays of all frequencies suffer absorption due to earth currents; these absorption losses are proportional to frequency and become very great at high frequencies. See ABSORPTION, DIFFRACTION, SPACE WAVE, SURFACE WAVE.

GROUND WAVE. Radio-wave which travels to the receiver over the surface of the earth and is not reflected by the ionosphere. See GROUND RAY.

GROUP DELAY. Time taken for a wave to travel between two points. It is given by the distance travelled by the wave between the two points, divided by the group velocity. See GROUP VELOCITY.

GROUP FREQUENCY. Frequency of trains of oscillations or waves expressed in terms of the number of trains per unit time. In a spark system, the group frequency is equal to the spark frequency.

GROUP MODULATION. Process in which the same frequency is added to or subtracted from the frequency of a number of waves of different frequency, such waves representing several different messages sent by carrier transmission.

Group modulation is employed typically in carrier transmission over cables and open-wire circuits. A group of messages is transmitted by modulating carrier waves of different frequencies. This transmission occupies a given frequency band, within which there are a number of (single) sidebands in frequency juxtaposition. It may be convenient to transpose all the waves in the band to lie between higher or lower frequency limits. The process involved is called group modulation.

Group modulators are usually ring modulators. The complete band to be group-modulated is taken to the modulating-wave terminals of the modulator, and a local oscillator supplies the carrier wave. Thus the same carrier-wave frequency is added to, or subtracted from, all the waves comprising the several different transmissions. Filters must be used to separate the desired frequency bands at the output. See FREQUENCY-CHANGING, RING MODULATOR.

GROUP MODULATOR. See GROUP MODULATION.

GROUP VELOCITY. Velocity of a group of sinusoidal waves. It is the velocity of a characteristic feature of the wave envelope; the amplitude, for example. The group velocity is the velocity of the energy associated with the waves. It takes a certain time for a wave to travel between sender and receiver. The group velocity of a radio signal is the velocity of light, which is 186,000 miles per second. All waves transmitted through space travel at the same velocity, which is that of light waves. In transmitting waves through wires, the velocity of propagation is less than that of light. Waves of different frequency may travel at different velocities. See DELAY DISTORTION, PHASE VELOCITY, WAVE.

GUARD BAND. Term used in connexion with frequency bands used in sending a number of modulated carrier waves through the same medium Each message is transmitted on a separate channel characterized by a particular carrier-wave frequency (see CHANNEL). If the separation of carriers in a double-sideband system were exactly twice the highest modulation frequency, sidebands would not overlap. It would, however, be impossible to design filters with so sharp a cut-off as to ensure the full pass of one band and complete attenuation of waves outside this band. In consequence, a guard band is left between the sidebands of transmissions occupying adjacent channels. See CARRIER-WAVE TRANSMISSION, MODULATION, SIDEBAND, SIDEBAND WAVE.

GUIDED WAVE. Radio-wave travelling down, and controlled by, a hollow conducting tube known as a waveguide. Broadly speaking, waves travelling down ordinary transmission lines may be termed guided waves, but the term nowadays is usually reserved for wave-guide transmission. See WAVEGUIDE.

GUN. In a cathode-ray tube, the system of electrodes which produces and controls the electron beam.

GUN CURRENT. Total current produced by the electron stream emitted by the cathode of a cathode-ray tube.

H

H. Abbreviation for HENRY(S).

H$_2$S. See NAVIGATIONAL AID, RADAR.

HALF-WAVE AERIAL. Aerial which is approximately half a wavelength in physical length. More precisely, an aerial which resonates at a particular frequency in such a manner that there is a voltage-maximum point at each end and a single voltage-minimum point in the middle.

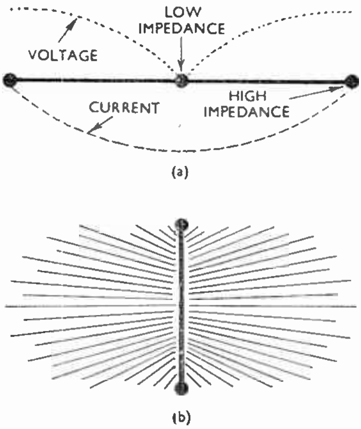


Fig. 1. Characteristics of a wire or rod behaving as a half-wave aerial. Diagrams show (*a*) impedance–voltage–current relationships, and (*b*) radiation, which is strongest perpendicularly from the axis of the aerial and nil in the end-on directions.

The half-wave section is a characteristic element common to most forms of aerial; the majority of aerial types can be built up from such sections. The quarter-wave aerial, for instance, is simply half a half-wave element, with the earth or a counterpoise system representing the missing half. A long aerial responding to some harmonic of its fundamental frequency does so in such a way that there is a series of half-wave patterns of voltage maxima and minima along the wire. Even a slot aerial possesses some of the properties of a half-wave element.

The half-wave mode of response is, in fact, the natural one for any isolated and elongated conductor exposed to a stimulus of appropriate frequency. An understanding of the general properties of the half-wave aerial is, therefore, a desirable preliminary to any study of aerials.

The voltage and current distribution along a wire resonating in half-wave fashion is shown in Fig. 1, which indicates that the current is large at the centre and zero at the ends, where there is, of course, nowhere for it to go. The voltage, on the other hand, is high at the ends and progressively lower towards the middle, the distribution being similar to that in a closed oscillatory circuit containing lumped inductance and capacitance (the differences between a resonating rod or straight wire and a closed circuit with lumped constants are mainly in details arising from the fact that the inductance and capacitance of the rod are spread uniformly along its length).

If connexion is made to a half-wave aerial at various points for the purpose

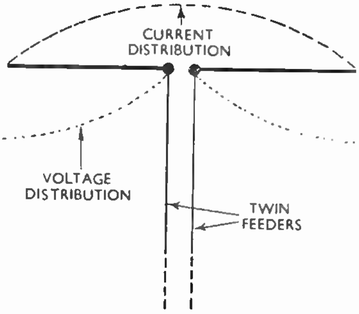


Fig. 2. In a half-wave aerial, current is highest at the centre and zero at the ends, while the voltage is low at the centre and high at the ends. The aerial shown is centre- (or current-) fed.

of injecting energy into it (for instance, by linking it to a sender through a twin-feeder line) its impedance seems to vary according to the position of the point of connexion. If the wire is cut in the middle and feeders are joined to the two halves (Fig. 2), the impedance of the aerial will appear low—about 80 ohms. At either of the two outer ends, on the other hand, the impedance is high—several thousand ohms.

These points of connexion are often useful in devising feed systems to suit various purposes; and further adjustments can be made by connecting feeders, not to an opening in the centre of the aerial, but across a length of the aerial chosen to give the desired impedance.

A half-wave aerial suspended vertically, and fed with energy from a sender, radiates uniformly in all horizontal directions, behaving as an omnidirectional aerial. There is practically no radiation from the ends of such an aerial, and no energy is directed upward or downward.

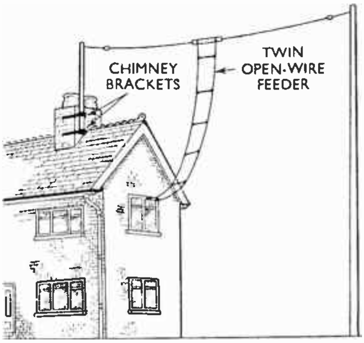


Fig. 3. Centre-fed horizontal half-wave dipole with slung open-wire feeder, the wires of which are spaced a few inches apart by rod insulators.

A half-wave aerial slung horizontally gives a figure-of-eight horizontal polar diagram. This is similar to the polar diagram of a loop-aerial, because of the absence of radiation from the two ends. If several half-wave elements are grouped side by side in an array and energized appropriately, the figure-of-eight becomes more and more elongated the greater the number of half-wave units; this is the basis of the broadside array. (If the half-wave elements are grouped vertically, a figure-of-eight polar diagram results, this replacing the circular polar-diagram characteristic of the single vertical aerial.)

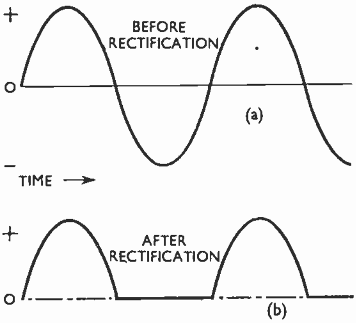


Fig. 4. In half-wave rectification, only one half of the wave is used to produce unidirectional current. If alternate half-cycles of wave (*a*) are suppressed wave (*b*) is the result.

In practical applications, it is probably more often desired to produce a beam strengthened in one particular direction than a two-direction figure-of-eight diagram. This can be done with half-wave elements by using a broadside array backed at a suitable distance by a second array of passive aerials to act as reflectors When excited by the radiation from the active aerials, these in their turn emit waves which reinforce those in a forward direction and tend to cancel out with those going back behind the array (see PASSIVE AERIAL).

The practicability of the half-wave aerial in its basic form is a matter of wavelength. Above rather indefinite limits this aerial becomes unwieldy, and below another limit it again ceases to be practicable because of unexpectedly acute difficulties in adjusting it accurately to wavelength. The upper and lower wavelength limits are in the region of 40 metres and 10 centimetres; but horizontal half-wave aerials of much greater length are sometimes used, and shorter ones have been common in connexion with laboratory work for a long time. See AERIAL, AERIAL-ARRAY, BROADSIDE ARRAY, HALF-WAVE DIPOLE, OMNI-AERIAL, PASSIVE AERIAL, TIER.

HALF-WAVE DIPOLE. Length of wire, rod or tube, usually straight, approximately one half-wave in length, in which the current and voltage distribution is symmetrical about the centre point. This type of aerial is of considerable importance at the higher frequencies. It is used, normally without earth connexion, both for sending and receiving, commonly with a twin feeder connected to the centre (Fig. 3) where the two halves of the dipole are separated for the purpose (see CURRENT-FED AERIAL, VOLTAGE-FED AERIAL).

When maximum efficiency at a fixed wavelength is required, the half-wave dipole is made approximately 0·97 of the actual half wavelength, allowance thus being made for the effect of insulating supports and the like. A half-wave dipole aerial may be erected horizontally or vertically, according to the direction of polarization of the waves to be radiated or received. See HALF-WAVE AERIAL.

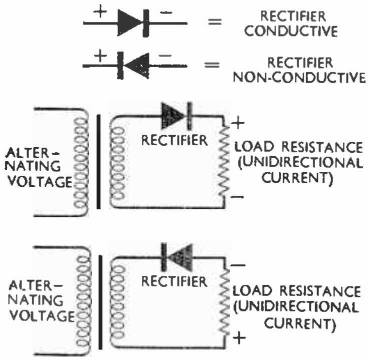


Fig. 5. Basic circuit of a half-wave rectifier; the element is conductive only during alternate half-cycles of the voltage induced in the secondary winding of the transformer.

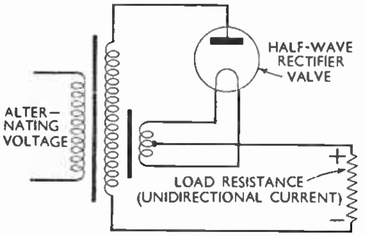


Fig. 6. Basic circuit for a diode used as a half-wave rectifier.

HALF-WAVE RECTIFICATION. Method of rectification in which unidirectional current is produced during one or another half-cycle of the wave being rectified. The results of half-wave rectification are shown in Fig. 4; it should be compared with that elsewhere illustrating FULL-WAVE RECTIFICATION. See also HALF-WAVE RECTIFIER CIRCUIT.

HALF-WAVE RECTIFIER CIRCUIT. Rectifier circuit in which a single rectifier unit is connected between a source of A.C. and the load to be supplied with D.C. Typical circuits for producing half-wave rectification are shown in Figs. 5 and 6.

Obviously it is not so efficient as full-wave rectification and has the disadvantage that the unidirectional current flows in the transformer secondary, thus magnetizing the transformer core. The circuit has practical use for detection. A circuit employing a mechanical rectifier is shown at Fig. 7. See FULL-WAVE RECTIFICATION, HALF-WAVE RECTIFICATION.

HALF-WAVE SUPPRESSOR COIL. Inductor placed at half-wave intervals along an aerial in which it is desired to suppress radiation in reverse phase from alternate half-wave sections. The arrangement is applicable only to aerials, such as the Franklin, with a

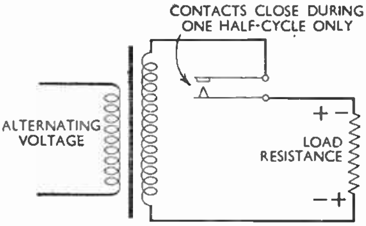


Fig. 7. Mechanical half-wave rectifier; the contacts close at the instant the alternating voltage is zero and open when the value is again zero, remaining so for the next half-cycle, and so on. The current in the load resistance is thus unidirectional.

length large compared with the half wavelength. See FRANKLIN AERIAL.

HAM. Term applied to amateur who operates a radio station.

HARD-VACUUM VALVE. Valve in which the amount of gas is so small that it has substantially no effect upon the operating characteristics of the valve. The space current is carried by electrons, not by ions. The hard-vacuum valve is one in which a proportionality exists between electrode voltages and electrode currents over large portions of the characteristic. It can thus be used as an amplifier, detector and oscillator. The GAS-FILLED VALVE (q.v.) is one in which the valve has virtually two conditions, conductive or non-conductive. See GLOW-TUBE, SOFT-VACUUM VALVE, VALVE.

HARD VALVE. Synonym for HARD-VACUUM VALVE.

HARMONIC. Sinusoidal oscillation, the frequency of which is an integral multiple of some basic frequency, the latter being called the fundamental in this connexion. Thus, an alternating current with a frequency of 50 c/s might have a third harmonic of 150 c/s, a fourth harmonic of 200 c/s, and so on. Harmonics are sometimes expressed in terms of wavelength. Thus, the third harmonic of a wave of 600 metres is a

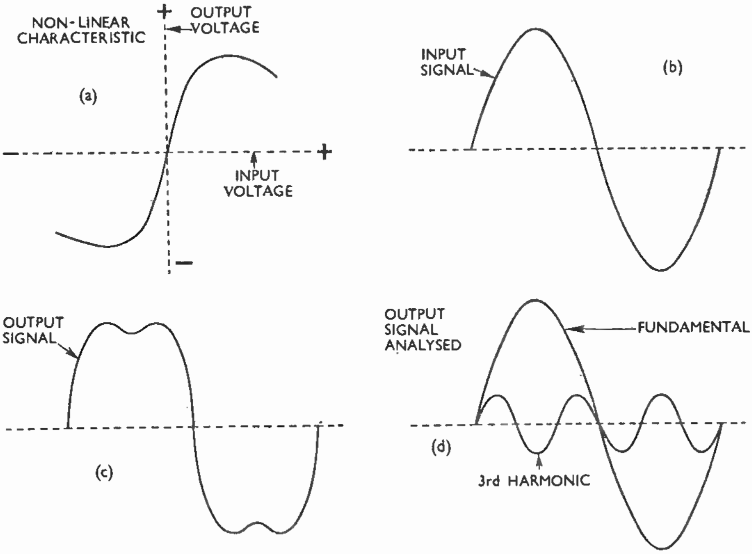


Fig. 8. Wave forms which illustrate the principles of harmonic distortion. If a pure sine wave (*b*) is applied to a non-linear device having, for example, an operational characteristic (*a*), the output is distorted (*c*). This output wave consists of a fundamental with the addition of one or more harmonics (*d*).

wavelength of 200 metres. Harmonics play an important part in sound reproduction; in complex sounds, such as those of speech and music, it is the relative amplitude of the harmonics to the fundamental which imparts the characteristic quality to a note.

HARMONIC AERIAL. Aerial designed to work on a frequency which is a harmonic, or multiple, of its natural frequency, and operating in standing-wave fashion. See NATURAL FREQUENCY, STANDING-WAVE AERIAL.

HARMONIC ANALYSER. See WAVE ANALYSER.

HARMONIC DISTORTION. Distortion of the wave form occurring when a signal of sine-wave form is applied to an amplifier or other system which is non-linear. As indicated in Fig. 8, the distorted output can be analysed into a fundamental sine wave having the same frequency as the input, together with harmonic waves (see FOURIER ANALYSIS, HARMONIC).

The harmonic distortion may be expressed quantitatively by stating the voltages of all the separate harmonics as percentages of the fundamental, or by giving the vector sum of all the harmonics present (total harmonic distortion; see DISTORTION FACTOR).

Triodes operating normally as amplifiers give mainly second harmonic; in tetrodes and pentodes the third harmonic is also liable to be prominent. Higher harmonics are relatively small unless the input/output graph has sharp bends.

In sound reproduction, the objectionableness of introduced harmonics increases very rapidly with the order of the harmonic. The ear can tolerate a considerable percentage of second harmonic, rather less third harmonic, and very little indeed of eleventh, thirteenth, etc. Total harmonic distortion is, therefore, not a satisfactory measure of distortion unless the proportions of harmonics present are approximately known or can be assumed.

In any case, the unpleasantness of non-linear distortion is due more to intermodulation than to harmonics, but the harmonic distortion being easier to measure is more often used as a measure of non-linearity. See INTERMODULATION DISTORTION, NON-LINEAR DISTORTION.

HARMONIC EXCITATION. Excitation of an aerial at a frequency which is an integral multiple of its natural frequency; or excitation of a transmitter at a frequency which is an integral multiple of that of the master oscillator.

HARMONIC GENERATOR. Any device delivering output power at a frequency which is an integral multiple of that of the input signal. For example, output of a frequency-doubler is twice the frequency of the input signal.

Harmonic generators may consist of a saturated iron-cored inductor or a valve operating on a non-linear portion of a characteristic, the desired output frequency being selected by means of a tuned circuit.

HARMONIC SUPPRESSOR. Network or filter which gives a large attenuation to an harmonic wave or waves, but transmits the fundamental component. See HARMONIC.

HARTLEY OSCILLATOR. Oscillator containing a parallel-tuned circuit connected between the anode and grid of a valve, a tapping point on the inductor being connected to the cathode or to the H.T. supply. Whether

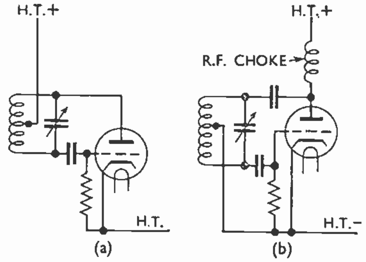


Fig. 9. Two forms of Hartley-oscillator circuit: (*a*) series feed; (*b*) shunt feed, including an R.F. choke.

the tapping point is connected to the cathode or to the H.T. supply, it is at zero alternating potential, and the mutual inductance between the two parts of the inductor provides the positive feedback between anode and grid circuits, which is necessary to maintain oscillation.

Two possible circuits for a Hartley oscillator are given in Fig. 9. In (a) the anode current of the valve passes through part of the inductor; thus all parts of the inductor and capacitor are at a steady H.T. potential with respect to earth. This disadvantage is often serious, but can be overcome by using the shunt-fed Hartley circuit shown in Fig. 9b.

In this the anode current passes through an R.F. choke, and the inductor is coupled to the anode circuit through a fixed capacitor, which is a barrier to D.C. but has low reactance to the A.C. generated. With this circuit arrangement the tapping point can be earthed.

HAY BRIDGE. A.C. bridge of the form shown in Fig. 10, generally used for determining the value of an inductor by comparison with a standard capacitor. When the bridge is balanced, minimum sound is heard in the headphones, and the following equations, where ω represents 2π times the frequency, apply:

$$L=\frac{R_3R_4C}{1+R_2^2\omega^2C^2};\quad R_1=\frac{R_2R_3R_4\omega^2C^2}{1+R_2^2\omega^2C^2}$$

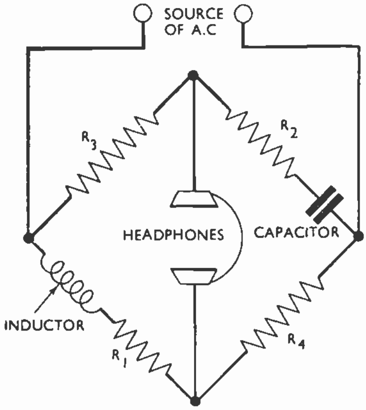


Fig. 10. Hay bridge as used to determine the value of an inductor by comparison with a standard capacitor.

HEADPHONE. Telephone receiver with head-band attached. It usually consists of a circular iron diaphragm placed over an electromagnet, the whole assembly being housed in a casing, with an insulated ear-piece to cover the diaphragm.

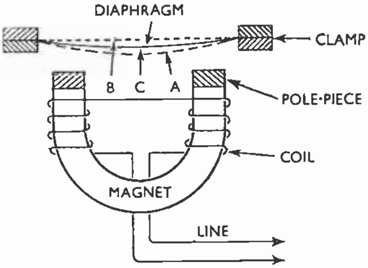


Fig. 11. Simplified diagram which shows how audio-frequency currents in the coil of a headphone, producing a varying magnetic field at the pole-pieces, cause alternate attraction and repulsion of the diaphragm, which thus vibrates at the frequency of the currents in the coil.

The principle of operation is as follows: A magnetic field is produced as shown in Fig. 11. The diaphragm is clamped around its periphery, its centre being drawn toward the magnet pole-pieces (position *C*). A current passed in one direction through the coil will increase the magnetic field and hence the pull on the diaphragm (position *A*). A current in the opposite direction decreases the field, causing the diaphragm to move away from the pole-pieces (position *B*). If the current is alternating, the diaphragm will be moved first in one direction and then in the other as the polarity of the current changes.

In practice, audio-frequency currents are applied to the coil, the diaphragm vibrating at the frequency of the applied signals. A pair of headphones is normally used for purposes of radio reception or programme monitoring in order to maintain aural balance.

HEAD TELEPHONE. Synonym for HEADPHONE.

HEARING. Subjective appreciation of sounds applied to the ear from an external source. See SPEECH AND HEARING.

HEARTSHAPE RECEPTION. Synonym for CARDIOID RECEPTION.

HEATER. Abbreviation for HEATER COIL.

HEATER COIL. That part of an indirectly heated cathode which raises the temperature of the emitting substance, thus causing it to emit electrons. The heater element is usually a coil of wire of considerable resistance. When a current passes through the heater it becomes red hot. The heater is placed inside, but insulated from, the cylindrical cathode. Fig. 12 shows typical heater-coil structures. See INDIRECTLY HEATED CATHODE.

HEATER CURRENT. Current flowing in the heater coil of an indirectly heated cathode. See INDIRECTLY HEATED CATHODE.

HEATER EFFICIENCY. See CATHODE EFFICIENCY.

HEATER SATURATION. See EMISSION LIMITATION.

HEATER VOLTAGE. Voltage applied to the heater coil of an indirectly heated cathode.

HEAVISIDE LAYER. See E-LAYER, IONOSPHERE, KENNELLY-HEAVISIDE LAYER.

HECTOMETRIC WAVE. Radio-wave between the wavelength limits of 100 and 1,000 metres, that is, within a frequency range of 3 Mc/s–300 kc/s. See MEDIUM-FREQUENCY WAVE.

HEDGEHOG TRANSFORMER. Transformer whose core is formed by iron wires the ends of which are bent over to form a partially closed iron circuit. The transformer is not much used nowadays. So much progress has been made in suiting laminations to particular requirements as to render other types of core, except iron-dust cores, obsolescent. See CORE. TRANSFORMER.

HEISING MODULATOR. Synonym for ANODE MODULATOR.

HELIX. Term used to describe an obsolete type of inductor of air-spaced copper strip, wound in the form of a clock spring.

HENRY. Practical unit (abbreviated H) of inductance, of convenient magnitude for the rating of inductors with iron cores. For smaller values, such as those found in inductors without cores used for tuning and other purposes in radio-frequency work, the millihenry (abbreviated mH) and the microhenry (μH) are used; these represent a thousandth and millionth part of a henry respectively. The henry is defined as the amount of inductance required to set up a back-e.m.f. of one volt when the current through it is changing at the rate of one ampere per second.

HEPTODE. Valve with seven electrodes, used for frequency-changing; it is also known as a pentagrid. See FREQUENCY-CHANGER VALVE.

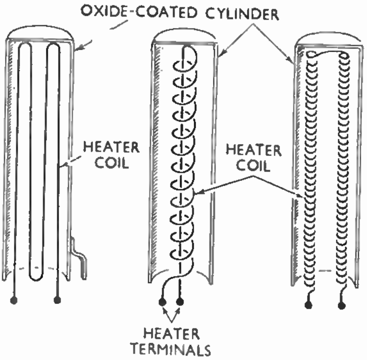


Fig. 12. Three typical forms of heater coil used to raise the temperature of cathodes of indirectly heated valves. The wire which forms the heater is invariably of tungsten.

HERTZIAN OSCILLATOR. See OSCILLATOR.

HERTZIAN RADIATOR. Synonym for HALF-WAVE DIPOLE.

HERTZIAN WAVE. Synonym for ELECTROMAGNETIC WAVES.

HETERODYNE. Term used to denote what is now properly known as BEATING.

HETERODYNE DETECTOR. Device for detecting continuous waves. The rectification of a C.W. signal provides a direct current of constant amplitude, which will produce no response in a pair of telephones except for a click at the beginning and end of the signal; moreover, the detector output cannot be amplified at A.F. For C.W. reception, it is usual, therefore, to modulate the signal at the receiving end. This is done by mixing the received signal with a locally generated signal of slightly different frequency.

Beats are produced between the two frequencies, the strength of the combined current being a maximum when the two currents are oscillating in phase. A short while afterwards, however, due to the difference in frequency between the signals, one oscillation begins to lag behind the other, and later an instant is reached at which they are oscillating in exactly opposite phase.

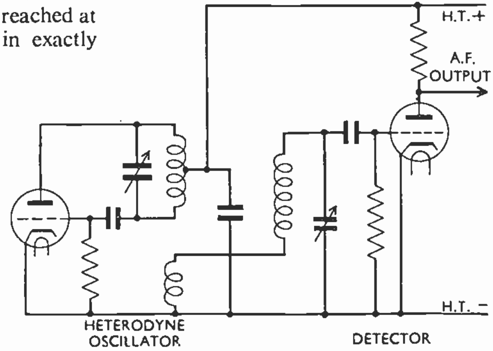


Fig. 13. Circuit of a simple heterodyne detector. A voltage from the local oscillator is induced into the signal-frequency circuit, and the combined signal is then rectified by the grid detector.

In this condition, the combined signal will be a minimum, and the strength of the combined signal will thus vary between a maximum and a minimum periodically. It can be shown that the frequency of this beat is equal to the difference in frequency between the local oscillation and the incoming signal.

A simple heterodyne detector is shown in Fig. 13. It is still necessary to rectify the resultant signal, because this is still at a radio frequency although it is now modulated in amplitude at the beat frequency. Hence a voltage from a local oscillator is induced into the signal-frequency circuit, and the combined signal is rectified by a grid detector.

Theoretically, a heterodyne detector should obey a square law so that the output is proportional to the square of the input signal. Only under such conditions is the output free from distortion.

Since C.W. signals, however, are usually telegraph signals, distortion is of minor consequence. On the other hand, a square-law detector provides an output which is proportional to the product of *both* signals, so that, by using a strong local oscillation, substantial amplification can be obtained during the detection process.

Heterodyning, however, is usually performed nowadays by an electronic mixer such as is used in superheterodyne receivers (Fig. 14). Such a valve provides an output proportional to the product of the incoming and local signals in the same way as does a square-law detector. See BEAT, BEATING, FREQUENCY-CHANGER, FREQUENCY-CHANGER VALVE.

HETERODYNE FREQUENCY METER. Stable radio-frequency oscillator, accurately calibrated, which can produce an audible beat with another oscillation, or with a signal, the frequency of which is to be measured. The meter is adjusted to zero beat, when the calibration reading indicates the frequency of the oscillation being investigated.

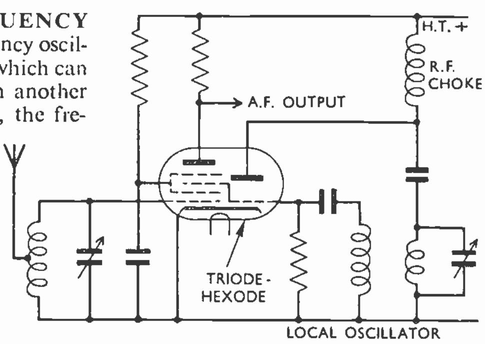


Fig. 14. Normal practice is to use a triode-hexode as a heterodyne detector; its output is proportional to the product of both the incoming and local signals.

HETERODYNE OSCILLATOR. Synonym for BEAT OSCILLATOR.

HETERODYNE RECEPTION. Synonym for BEAT RECEPTION.

HETERODYNE WHISTLE. See INTERFERENCE.

HEXODE. Valve with six electrodes. See FREQUENCY-CHANGER VALVE.

HIGH-DEFINITION TELEVISION. Name given to any system of television in which the scanning provides for more than 200 lines for each picture. Television commenced with low-definition systems, such as the 30-line mechanical method used originally by Baird.

Television is a highly complicated process, in which a scene, with all its details and light and shade, must be converted from a combination of reflected light rays into a series of electrical impulses which can be made to modulate a radio signal, and the process then reversed so that a replica of the original combination of light rays is produced. All this must be done in such a way that not only is movement transmitted, but that light and shade is retained in its original gradations.

A given source of light is caused to actuate a photocell. It is easy to vary the intensity of the light and by so doing vary the potential developed in the cell. With this single light source it is not difficult to go a step further and cause the variations in light, by means of the variations in potential in the cell, to modulate a radio sender so that the brighter the illumination, the greater the carrier amplitude obtained.

Moreover, the received signal can be made to modulate a lamp or a cathode-ray tube so that we obtain an increase in light on our screen as the original light increases in intensity, and a decrease as the light becomes less intense. That is the basis of television.

Now consider a scene. It is composed of myriads of points of light, of different and, as the picture moves, changing light intensity which may be of any degree between black and white. This scene cannot be transmitted as a whole. Even if we had myriads of photocells, one for each point of the picture, we could not transmit electrical impulses from all the cells at once.

The alternative is to transmit the impulses in sequence, each impulse corresponding in amplitude to the illumination of a point or element in the scene. Each element is dealt with in its proper order so that a "string" of signals is obtained. At the receiver, the string is laid out on the television screen in the right sequence and the picture is built up again.

The number of elements into which the field of view is divided determines the definition. The size of the elements also affects the detail seen on the receiver screen, since it is the light intensity from the whole of each element that affects the transmitter modulation and we cannot deal with any gradation of light within the area of one element.

Television, therefore, is based on a system which is similar to that used in printing, namely, the division of the picture into small units which, when laid down in their correct relative places, re-form the picture. The action of the retina of the eye works on a similar plan, being built up of small cells each of which plays its part by dealing with one element of the scene being viewed.

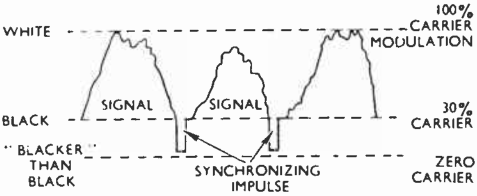


Fig. 15. Example of the transmitted wave form in high-definition television. As the synchronizing impulses are below the 30 per cent carrier-modulation level (at which the receiver screen shows no illumination), they are invisible.

For the method used to provide an orderly transmission of the picture, see SEQUENTIAL SCANNING. The camera employed is fully described elsewhere (see STORAGE CAMERA). We can, therefore, pass on to a more general consideration of the high-definition system, as used by the B.B.C. Other systems are similar in fundamentals, so that there is no need to describe them also.

The method of scanning used employs the principle of interlacing (see INTERLACED SCANNING). Thus, in a 405-line picture, the alternate lines 1, 3, 5, 7, 9 and so on are scanned up to 405, and then the scanning is repeated with lines 2, 4, 6, 8 and so on to line 404. The effect on the eye is to provide a continuous picture such as would be obtained by the scanning of successive lines throughout, but with the illusion that the picture is being scanned at twice the actual speed. A picture scanned *completely* 25 times in every second gives the impression, assessed by its lack of flicker, that it is being scanned 50 times a second.

This is more important than it seems, for, while the apparent picture-frequency has been raised to 50 per second, the actual picture-frequency is only 25. In practice, this has technical advantages. One is that certain types of motional distortion are reduced. Another is that large patches of equal light intensity, which would in sequential scanning produce low electrical frequencies, are made to provide frequencies of a higher order since the scanning spot is not on the object so long without change in intensity.

A great advantage in interlaced scanning is the reduction of the frequency band that the sender and receiver have to cover. This band width can be determined mathematically by a simple formula.

It can be assumed, without serious error, that the single impulse of potential produced as the scanning ray traverses each picture-element in the storage camera is similar to a sinusoidal half-wave form, and of amplitude proportional to the light intensity of the element in question. The scanning of the elements proceeds at a constant rate, so that the electrical impulses follow one another at a definite frequency, producing an electrical frequency equal to half the number of elements scanned per second. This frequency is the maximum frequency which the sending and receiving circuits will have to handle. Let us call that frequency f.

In a square picture, with N scanning lines each the width of an element, there will be N^2 elements. If the picture-frequency is F, the number of elements scanned per second will be N^2F. It can thus be stated that $f = \frac{N^2F}{2}$. With 405-line scanning and 25 pictures a second, the frequency is therefore $\frac{405 \times 405 \times 25}{2}$ where a square picture is concerned.

In the B.B.C. system, however, the picture ratio, sometimes referred to as the aspect ratio, is 4 : 3 (see PICTURE RATIO). So, instead of N^2 in the above formula, we use $N^2 \times P$, where P is the picture ratio, and the formula becomes $f = \frac{N^2 \times P \times F}{2}$. Substituting figures, we have $\frac{405 \times 405 \times 4 \times 25}{3 \times 2}$, which works out at just over 2,700,000 in round figures, or a frequency of 2¾ megacycles per second. That, then, is the modulation frequency that has to be dealt with, so that the sidebands will occupy a band width of 5½ Mc/s.

To accommodate such sidebands, it is obvious that a high-frequency carrier must be used. The British system employs a carrier of 45 Mc/s for the vision signal, and 41·5 Mc/s for sound. The high vision frequency (2¾ Mc/s) requires exceedingly well-designed radio-frequency circuits in sending and receiving amplifiers, and provides serious problems of attenuation and phase distortion, not only in the amplifying circuits, but particularly in any form of line transmission.

The mean brightness of the reproduced picture depends on the D.C. component of the vision signal, and an ideal vision-frequency amplifier must be able to amplify steady potentials in addition to the range of frequencies up to 2·7 Mc/s. The necessity for D.C. amplification does not present any serious problems in television-receiver design because most receivers have only a single stage of vision-frequency amplification, and it is comparatively easy to couple this directly to the diode detector preceding it and to the cathode-ray tube which follows it.

In television senders, however, and in multi-stage vision-frequency amplifiers generally, the design becomes very difficult if direct coupling is attempted throughout, and it is easier to use conventional resistance-capacitance coupling designed for a very low-frequency cut-off, and to use a stage of D.C. restoration at or near the final stage to supply the missing D.C. component.

As every frame is accompanied by a frame-synchronizing impulse, the lowest frequency with which the sender and receiver have to deal is the repetition frequency of this impulse. In the B.B.C. system it is 50 c/s, for, though only 25 pictures are transmitted in a second, the scanning lines have to be returned to the top of the picture 50 times a second, because of the interlacing in which the scan begins alternately at the first and the second line.

Both sender and receiver make use of the inertia-less cathode-ray tube. The camera uses it to scan a special photocell mosaic (see STORAGE CAMERA), and the receiver employs the cathode-ray tube as a means of building up the picture on a fluorescent screen.

It is easy to understand how the intensity of the light from the cathode-ray screen is made to vary by grid control of the number of electrons in the cathode-ray stream. It is not so easy, however, to see, at first, how the cathode-ray tube can be synchronized with the storage camera. The transmitted wave form of a high-definition television signal (Fig. 15) will help to make this point clear.

The carrier, unmodulated by the television signal, is set at a constant level corresponding to 30 per cent modulation. The signal is made to vary modulation *above* this figure. It never causes the modulation to drop beneath 30 per cent.

Therefore, if the receiver cathode-ray tube is so set that it is unmodulated (shows black) when the carrier is at 30 per cent, it will respond only to carrier variations between 30 and 100 per cent. It *cannot* be affected by any variation below 30 per cent. Any fall in the modulation below 30 per cent is known as "blacker" than black. It is in this range of modulation that the line- and frame-synchronizing impulses are sent, the carrier being reduced from 30 per cent to zero at each pulse.

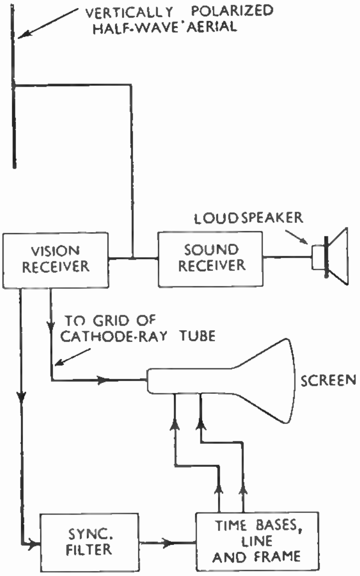


Fig. 16. Schematic diagram of a television receiving system. Synchronizing impulses are separated from the picture impulses by an amplitude filter in the vision receiver.

An amplitude filter in the vision-receiver circuit filters the synchronizing impulses from the vision-modulation (picture) signals, and special circuits (Fig. 16) are used to separate the line- from the frame-synchronizing impulses.

Each receiver cathode-ray line time base is so designed and set that, after each line, the electron beam flies back and waits for the synchronizing signal to trigger it off on the scan of the next line. Similarly, at the end of each frame (line 202 or 405), the electron beam is returned to the top of the screen by the frame impulse.

During the synchronizing impulses all vision signals are suppressed at the sender, and after each line-synchronizing impulse the carrier level is carefully restored to 30 per cent by special restoring circuits. It is essential for correct definition and picture reproduction that the carrier wave's basic modulation level of 30 per cent be accurately retained. It is re-set, therefore, before the commencement of each line.

Both T.R.F. and superheterodyne receivers are used, the former using about four R.F. stages tuned to 45 Mc/s, a band width of at least 4 Mc/s being essential in all receivers. Care must be taken that the number of stages of amplification after the R.F. detector is such that the picture modulation is positive. Phase-reversal takes place at each stage and, unless the correct phase is obtained at the output of the last stage, the picture will be reproduced in negative form.

HIGH FIDELITY. Qualitative term describing an amplifier or electro-mechanical device such as a loudspeaker or gramophone pick-up capable of giving reproduction which is remarkably faithful to the original. The term "high quality" is sometimes used in the same sense. See AMPLIFIER, BROADCAST RECEIVER, LOUDSPEAKER.

HIGH FREQUENCY. Relative term usually referring to high-frequency radio-waves of 3–30 Mc/s in frequency, that is, within a wave range of 10–100 metres. See HIGH-FREQUENCY WAVE.

HIGH-FREQUENCY ALTERNATOR. Synchronous generator for producing currents at very much higher frequency than is used for supply purposes. See SYNCHRONOUS GENERATOR.

HIGH-FREQUENCY AMPLIFICATION. Synonym for RADIO-FREQUENCY AMPLIFICATION.

HIGH-FREQUENCY CHOKE. Obsolescent term for RADIO-FREQUENCY CHOKE.

HIGH-FREQUENCY RESISTANCE. Resistance at radio frequency of a circuit, component or particular conductor. The resistance at high frequency is normally considerably in excess of the low-frequency figure because high-frequency currents tend to travel mostly on the surface of a conductor and do not make use of the inner area of the cross-section, and because they are subject to greater eddy-current and dielectric losses; both of these are included in the high-frequency resistance, in addition to the ordinary D.C. resistance of the particular section of the conductor which high-frequency currents occupy. See DIELECTRIC LOSS, EDDY CURRENT, SKIN EFFECT.

HIGH-FREQUENCY TRANSFORMER. Synonym for RADIO-FREQUENCY TRANSFORMER.

HIGH-FREQUENCY WAVE. Radiowave between the frequency limits of 3 and 30 Mc/s, that is, within a wave range of 10–100 metres. Waves within this frequency band are commonly known as short waves. The longer wavelengths in this band are reflected by the E-layer, but no hard and fast dividing line can be laid down because the division depends upon the degree of ionization in the E-layer, which varies with the time of day and season of the year. The energy loss whilst the wave is in an ionized region is small, and short waves are reflected from the E-layer with relatively little loss, the attenuation being proportional to $1/f^2$, where f is the frequency. The least attenuation is therefore obtainable with the shorter wavelengths.

As the frequency is increased, a point is reached at which the bending in the E-layer is insufficient to return the wave to earth, and the wave continues on through space until it reaches the F-layer. At the F-layer the intensity of ionization is sufficient to reflect the wave and it ultimately returns to earth.

If the frequency of the wave is higher than the critical frequency of the F-layer, the wave passes right through the F-layer and disappears into outer space. For the normal waves used for broadcasting and commercial practice, most of the reflection takes place at the F-layer. See ABSORPTION, CRITICAL FREQUENCY, E-LAYER, F-LAYER, IONOSPHERE, IONOSPHERIC REFLECTION, MEDIUM-FREQUENCY WAVE.

HIGH-LEVEL MODULATION. Synonym for HIGH-POWER MODULATION.

HIGH-PASS FILTER. Filter which transmits waves having frequencies higher than the cut-off frequency with less attenuation than those having frequencies lower than the cut-off frequency. Fig. 17 shows the basic configurations of a high-pass filter; the shape of its attenuation-frequency characteristic is illustrated in Fig. 12 (page 227) under the heading FILTER. See also BAND-PASS FILTER, FILTER SECTION, LOW-PASS FILTER.

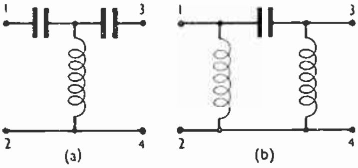


Fig. 17. Basic forms of high-pass filter: (*a*) T-section; (*b*) π-section.

HIGH-POWER MODULATION. Modulation in which the output from the modulated amplifier is passed directly to the transmission channel without further amplification. In order that intelligence may be transmitted, a carrier-wave sender, of any form, must contain a modulator (in telegraphy, the modulator is equivalent to the sending key). Modulation of the carrier wave may take place when this has its maximum power, or, on the contrary, may take place at such a relatively low power that the modulated wave must be amplified before being applied to the transmission channel. This is called low-power modulation (Fig. 18).

There are certain advantages and disadvantages in both systems; some broadcasting senders use high-power, some low-power modulation; neither is definitely better in all respects than the other. See LOW-POWER MODULATION.

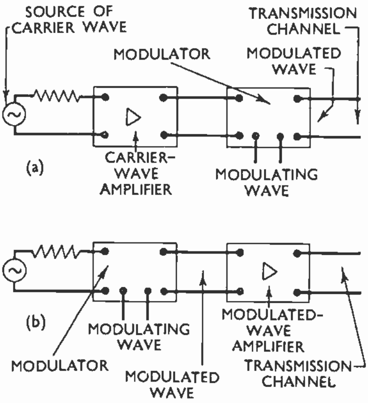


Fig. 18. Schematic diagrams which distinguish between (*a*) high-power and (*b*) low-power modulation.

HIGH-SPEED KEYING. See KEYING.

HIGH-STOP FILTER. Synonym for LOW-PASS FILTER.

HIGH TENSION. Term used in telecommunication practice to describe a source of anode voltage; the abbreviation is H.T. The direct voltage supplied to the anode circuits of valves is usually relatively greater than that used to heat valve cathodes or to establish any fixed grid potential; thus the use of the word "high" to distinguish it.

In installations using considerable power, the high-tension supply may come from direct-current generators or from mercury-arc rectifiers or mercury-vapour rectifiers energized from the mains power supply. In smaller installations, vacuum-valve rectifiers are commonly used to convert the alternating voltage of the mains to a direct voltage.

Batteries may be used for H.T. supply and have a lower internal resistance than that of ordinary mains units of similar capacity. They also eliminate all possibility of the hum which is prone to exist in mains units.

The virtues of any high-tension source are assessed in terms of low internal impedance (giving good regulation) and the diminution of a common coupling impedance which tends to produce instability in valve amplifiers (see MOTOR-BOATING). Low first cost and low maintenance cost, high power-efficiency, reliability and freedom from hum voltage are other important features.

A voltage-stabilized mains unit has many advantages, but has a low power-efficiency. Mercury-arc rectifiers meet the requirements demanded by big power installations, and the mains units using vacuum-valve rectifiers score in simplicity and reliability where only a small output is required. See HIGH-TENSION BATTERY, HUM, MAINS UNIT, VOLTAGE-STABILIZED MAINS UNIT.

HIGH-TENSION BATTERY. Battery of voltaic cells used to supply current to the anode circuit of a valve or valves. Dry-cell high-tension batteries are formed from a number of units having usually a nominal total voltage of 60, 90 or 120 volts maximum. Assuming 1·5 volt per cell, 60 cells are mounted in one unit to form a 90-volt battery (Fig. 19). Tappings are made at various voltages on some batteries; others have + and – connexions only.

Some manufacturers add one or two more cells in a group of 40 to maintain the full battery voltage when the voltage of each cell has fallen a little due to ageing.

A battery may deteriorate even though not used, partly because the container, particularly if damp, becomes conductive and causes the cells to discharge current through it. For this reason, among others, each unit of a battery has a limited maximum voltage. To build a 200-volt high-tension battery all in one unit would be to shorten what is known as its "shelf-life." Batteries have a very short life in the tropics unless special precautions are taken to keep them both cool and dry.

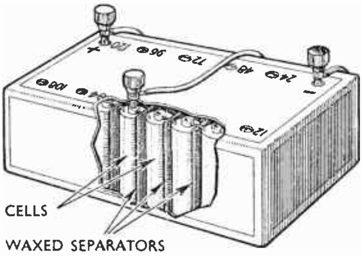


Fig. 19. A 120-volt high-tension battery with tappings. The case is shown partly cut away to reveal some of the cells and separators.

The average high-tension battery supplied for portable radio receivers gives about 5 mA during intermittent discharge periods for a few months. The rating is of the order one ampere-hour (see AMPERE-HOUR CAPACITY).

Small accumulator cells may be used as the units of a high-tension battery, but they require a good deal of attention, demanding constant charging, topping-up, and inspection for sulphating; they have, however, the advantage of a smaller internal resistance and a higher output current than have commonly used types of dry-cell battery.

In very large installations where many amplifiers may be energized from a common high-tension battery, the batteries may be formed from cells having even a 20-ampere-hour capacity. The very low internal impedance of such a battery is its chief recommendation; there is also the fact that it does not produce hum—as would a mains unit unless very special precautions were taken.

High-gain amplifiers, the input to which is at a very low power level, are sometimes energized from batteries in order to avoid any hum voltage. See ACCUMULATOR CELL, DRY CELL, VOLTAIC CELL.

HIGH-TENSION KEYING. In radio telegraphy, the keying of the sender by making-and-breaking the supply circuit to the anode of one or more of the valves.

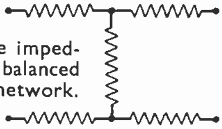
HIGH-TENSION POWER SUPPLY. Source of electrical energy which maintains the anodes of valves positive with respect to their cathodes. In portable receivers the high-tension power supply is generally a dry battery known as the high-tension (H.T.) battery; in A.C.-mains receivers the high-tension power supply is a rectifier and smoothing circuit. See HIGH TENSION, HIGH-TENSION BATTERY.

HIGH-VACUUM VALVE Synonym for HARD-VACUUM VALVE.

HILL-AND-DALE RECORDING. Recording system, particularly gramophone, in which the recording stylus moves up and down in a plane perpendicular to that of the surface of the material. A sound track thus produced varies in depth as the frequency and amplitude of the sound varies. See ELECTRICAL RECORDING.

H-NETWORK. Network composed of five impedances, as shown in Fig. 20.

Fig. 20. H-network of five impedances; it is the balanced form of the T-network.



The H-network is the balanced form of the T-network. See C-NETWORK, L-NETWORK, T-NETWORK.

HOMING SYSTEM. Method of using the direction-finding equipment carried by an aircraft for obtaining the position of a ground radio station. It enables the pilot to fly the plane directly towards the sender.

In early systems a simple loop aerial was used, and the output of the receiver was connected to a differential type of instrument with a centre zero; this gave a zero reading when no e.m.f. was induced in the loop and a reading to left or to right when a signal was received. This visual method is preferable to audible methods because of the very high noise level prevalent in an aircraft.

To use the equipment for "homing," the loop aerial is set at right-angles to the fore-and-aft line of the plane, which is steered so as to obtain a zero reading when the receiver is tuned to the chosen sender (which can be a broadcast sender). This simple system has two disadvantages: it is impossible to tell whether the plane is flying directly towards or away from the sender; and the sender may cease radiating without the pilot being aware of it.

To overcome these disadvantages, a different method was adopted: an instrument was developed having twin pointers which intersect on a centre line if the course being flown is correct, but intersect to the left or the right when the plane leaves the correct course. The height of the point of intersection depends on the received-signal strength, which varies during the flight and thus shows if the transmission ceases.

Between 1939 and 1945 various radar homing devices were developed, some of which give visual indication of the distance to the homing station in addition to information about the course. The most fully developed of these is known as "Rebecca-Eureka."

The distance reading is obtained by sending out pulses from the aircraft, which are received at a ground station and trigger a sender which also radiates pulses. These are received in the aircraft, and the time interval between the sending of each original pulse to the reception of each answering pulse is measured and exhibited on the screen of a cathode-ray tube, the time base of which is calibrated in terms of distance.

For course indication, two directional dipoles are used, mounted to either side of the forward part of the aircraft fuselage, and arranged to produce a cardioid diagram on either side of the line of flight. A switch driven by a high-speed motor alternately connects each aerial to the receiver, and the amplitude of the two signals is compared by observation of the size of two traces, arranged to either side of a vertical time base, on a cathode-ray tube.

For homing, the pilot steers until the traces are of equal amplitude. Frequencies of the order of 200 Mc/s are used, and the range of the system is about 90 miles at a height of 5,000 ft.

HOMODYNE RECEPTION. System in which a locally generated oscillation is adjusted to and reinforces an incoming type A3 signal (see TYPE A3 WAVE).

HONEYCOMB COIL. Special type of wave-wound coil. See WAVE-WINDING.

HONEYCOMB-WOUND INDUCTOR. Synonym for LATTICE-WOUND INDUCTOR.

HORIZONTAL AERIAL. Aerial in which the major part or the pick-up property is concentrated in a horizontally arranged member or members. A low and very long inverted-L aerial can be thus described. See INVERTED-L AERIAL.

HORIZONTALLY POLARIZED WAVE. Radio-wave in which the plane of polarization of the electric field is horizontal. On short wavelengths where half-wave dipoles are used extensively for transmission, horizontally polarized aerial-arrays are commonly used together with horizontal receiving arrays.

There is, however, very little to choose between horizontal and vertical arrays at high frequencies, because reception is by means of the ionospheric ray, whose plane of polarization is almost invariably rotating after reflection. Distant reception is equally good with any type of aerial, irrespective of the polarization of the sending array. In areas where automobile-ignition interference is evident, it is sometimes advantageous to employ a horizontal receiving aerial, because ignition interference is usually vertically polarized. See POLARIZATION.

HOT CATHODE. Cathode raised to high temperature so that electrons are emitted. Such electrons, notably in a hard-vacuum valve, conduct current across the vacuum separating electrodes. The term "hot-cathode valve" distinguishes a valve from a glow-tube. See COLD-CATHODE VALVE, GLOW-TUBE, VALVE.

HOT-WIRE DETECTOR. Early form of detector utilizing the fact that the passage of current through a fine wire raises its temperature, which, in turn, alters its resistance. The detector is therefore arranged in the form of a bridge network which is normally balanced, so that no current flows in the indicator, as shown in Fig. 21. The radio-frequency signals to be detected pass through the arm *AB* of the bridge, thereby increasing the temperature of this arm and consequently causing its resistance to increase. This throws the bridge out of balance and a current flows in the indicator.

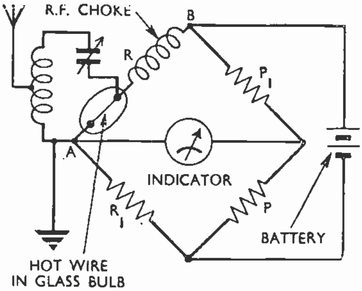


Fig. 21. Circuit of the hot-wire detector. The bridge is balanced, in the absence of a signal, by making $RP = R_1P_1$, R being the total normal resistance of arm AB, including choke.

Provided the change in resistance is small, the current in the indicator is directly proportional to the change of resistance; but the actual current in the indicator is many times greater than the radio-frequency current which gives rise to it. Hence the device not only performs the essential process of detection, but also provides some amplification.

HOT-WIRE MICROPHONE. Microphone depending for its action on the change of resistance of a conductor with change in temperature. In this instrument a wire is cooled by the passage over it of a sound wave, and the resulting resistance change is detected by telephones. The hot-wire microphone is now obsolete.

HOT-WIRE TELEPHONE. Instrument, now obsolete, working on the principles of the HOT-WIRE MICROPHONE (q.v.).

HOWLING. Audible note produced in a receiver in which excessive positive feedback is used, causing oscillation which beats with the received carrier wave. If the oscillation is radiated, the howling may be audible in neighbouring receivers also. See BEAT INTERFERENCE.

H.T. Abbreviation for HIGH TENSION.

H-TYPE ADCOCK DIRECTION-FINDER. Synonym for ELEVATED H-TYPE ADCOCK DIRECTION-FINDER.

HUM. Sound heard in telephones or loudspeakers due to low-frequency alternating currents. Hum voltages are most commonly produced by effects due to the alternating current of the mains supply. Where a mains unit is used, or the heaters of valves are energized from the mains, hum voltages are prone to be produced. Alternating fields, set up by low-frequency currents of large amplitude, may induce hum voltages in the first stages of high-gain amplifiers.

The principal causes of hum are:

1. Insufficient smoothing (or filtering) of the unidirectional currents

produced by the rectifiers in mains units.

2. The use of alternating current to heat the cathodes of valves.

3. Induction of alternating voltages in the amplifier circuits by stray fields set up by the alternating power-supply currents.

4. Insufficient smoothing of currents energizing the magnet systems of loudspeakers, when such devices are used.

There is, in nearly all cases, no reason why all audible hum should not be eliminated provided the cost of so doing is not prohibitive in relation to market and use. The root point is that, in many cases, a residual hum remains because the cost of the apparatus will not bear the extra money necessary to get rid of it.

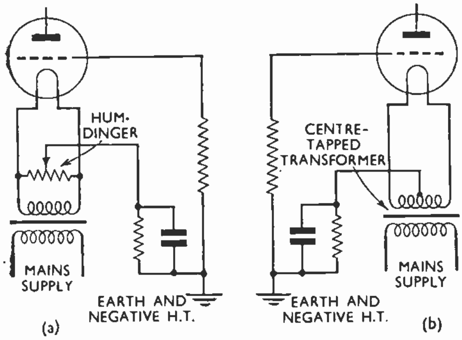


Fig. 22. Two methods of reducing hum in valves with filament-type cathodes: (*a*) by means of a hum-dinger, and (*b*) by the use of a centre-tapped filament transformer.

Hum arising from heating the cathode circuits of valves is partly, but not wholly, determined by the choice of circuit associated with heating the cathode. In valves with indirectly heated cathodes, hum voltages are produced due to the action of alternating electrostatic and electromagnetic fields, set up around the cathodes, which modulate the anode currents, just as superimposed grid voltages would.

In such valves, the fundamental frequency of the mains supply currents may be eliminated by biasing the heater positively in respect to the cathode to avoid electron emission from heater to cathode; this has no effect upon the second-harmonic component. The principal and most effective way to eliminate hum in indirectly heated valves is to provide efficient cathode screening in the design and construction of the valve. Valves with indirectly heated cathodes are available in which the inherent hum voltages are reduced below the level of thermal-agitation noise.

In filament-type valves, the design of the external circuit has a considerable effect in reducing hum. The hum-dinger, a potential divider arranged as in Fig. 22a, may be adjusted so that the mean alternating-current potential of the filament with respect to the anode is as near zero as possible. The use of the centre-tapped transformer is another way to reduce hum in filament-type valves (Fig. 22b). Both diagrams show how resistance in the cathode is used to bias the cathode positively with respect to earth potential.

Since the emission from a filament depends upon its temperature, and because the heating currents vary between a maximum and zero every half-cycle of alternation of the heating current, the anode current may, as a result, vary at twice the heating-current frequency. No external circuit (unless it be that which provides a direct-current heating source) will overcome this source of hum. The makers of the valves are to be trusted, however, to design the valve to reduce this type of hum to a minimum consistent with price and specified use.

Induction of hum in iron-cored inductors and transformers may be

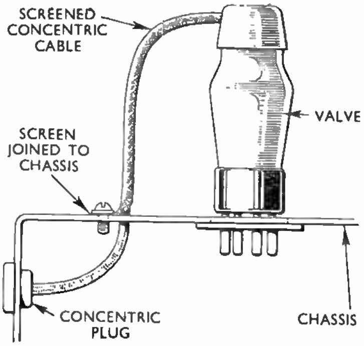


Fig. 23. Example of the use of a screened conductor to minimize electrostatic hum in the first stage of a high-gain audio-frequency amplifier.

reduced by placing these inside Mu-metal screens (an expensive method) or by the use of astatic windings for the transformers and inductors. Electrostatically introduced, hum can be eliminated by screening with copper or, in some cases, brass shields.

In a high-gain audio-frequency amplifier hum may be caused by electrostatic pick-up at high-impedance points (such as grid circuits). This can be minimized by screening and by use of screened wire (Fig. 23), provided that the capacitance introduced by such wire does not affect amplifier performance.

Hum may be caused also by magnetic pick-up in the wiring; this is most serious at low-impedance points in the circuit, and can be minimized by avoiding wiring loops, such as those caused by earthing screens at more than one chassis point.

A loudspeaker may be energized from a mains unit with insufficient smoothing and so set up hum; to eliminate this, a so-called hum-bucking coil may be employed. The improvement in the magnetic materials used for loudspeakers and the extra cost of using what is termed the energized type of magnet is, however, making this kind of loudspeaker obsolescent.

HUM-BUCKING COIL. Coil of a few turns close to, and in series with, the moving coil of an energized loudspeaker, used to reduce hum caused by inadequate smoothing of the D.C. supply.

HUM-DINGER. Tapped resistor that is used with an A.C.-heated valve in order to minimize hum. The resistor is connected in parallel with the filament of the valve, and the negative H.T. connexion is made to the tapping, this being situated in the electrical centre of the resistor (Fig. 22a).

HYBRID COIL. Transformer with four pairs of terminals, the windings being arranged in the form of a bridge circuit. A zero or small output appears at one pair of terminals when another pair is energized, provided that the third pair is connected to a suitable impedance. The hybrid coil has its chief use in telephone practice. It allows a two-way communication to be made on a single line without switching, and without the user being overwhelmed by too strong a reproduction of his own speech.

The diagram (Fig. 24) shows the circuit of a hybrid coil and the condi-

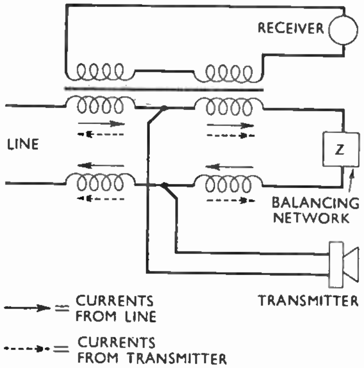


Fig. 24. Use of a hybrid coil in a telephone system. Signals from the line develop a voltage across the receiver, but, with a suitable balancing network, signals from the transmitter, although they are transmitted to the line, do not energize the receiver.

tions when a signal is received from the line or is transmitted to it. When currents are received from the line, the voltages developed across the two secondary coils are additive; but, provided the balancing impedance has the correct value, the secondary voltages connected to the receiver balance out when current is generated by the local transmitter. In practice, however, the balancing impedance is adjusted so that a small signal, known as a sidetone, is sent from the local transmitter to the local receiver. Note that the transmitter or microphone is connected to null points of a bridge circuit, and so does not absorb power from the line. There are many other uses of the hybrid coil, mostly concerned with measurement by bridge circuits. See BRIDGE NETWORK, LINE TRANSMISSION, TRANSMISSION LINE.

HYBRID TRANSFORMER. Synonym for HYBRID COIL.

HYDROMETER. Instrument used to measure the specific gravity of a liquid. The principle of the hydrometer (Fig. 25) is based on the fact that the upward force on a body in a liquid is equal to the weight of liquid displaced. The heavy shot in the bottom of the tube makes it float in a vertical position and the scale registers how deeply it floats; the scale is marked in values of specific gravity.

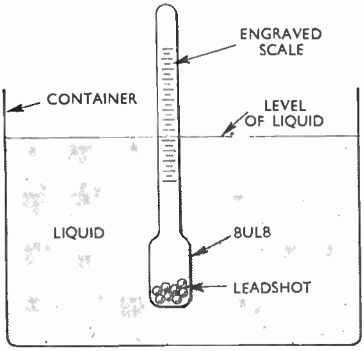


Fig. 25. Diagram illustrating the principle of the hydrometer. Graduations on the stem are in values of specific gravity, the reading being made from the scale at the level of the liquid.

It is important to maintain the specific gravity of the acid in accumulators at a certain value, and a hydrometer is essential in the practice of accumulator maintenance. In larger cells which stand always in one place, the top (usually a glass plate) may be removed and the hydrometer dropped in to the liquid beside the lead plates.

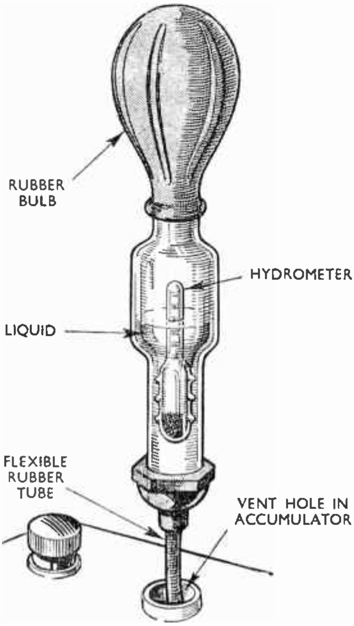


Fig. 26. Usual form of hydrometer for testing the specific gravity of acid in sealed accumulator cells.

In portable accumulators, however, which are sealed except for the vent holes, an arrangement such as that shown in Fig. 26 is used. Squeezing and releasing the rubber bulb sucks the liquid into the glass container and the hydrometer floats in the liquid.

The specific gravity of the acid varies with the charge in the accumulator. In certain makes of accumulator, a pointer, the position of which is determined by the specific gravity of the acid in the accumulator, registers the charge in the cell as "Full," "¾," "½," "¼," "0," the pointer and its mechanism constituting an hydrometer.

HYPERBOLIC NAVIGATION. System of navigation in which a craft's position is determined on a lattice of hyperbolic lines. These hyperbolae denote a constant difference of distance from two points which are synchronized, ground-based, sending stations. See NAVIGATIONAL AID.

HYPERFREQUENCY WAVE. Synonym for SUPER-FREQUENCY WAVE.

HYSTERESIS FACTOR. Proportion of the total loss in a capacitor which is due to hysteresis in the dielectric.

I

ICONOSCOPE. See STORAGE CAMERA.

I.C.W. Abbreviation for interrupted continuous wave, a synonym for TYPE A2 WAVE.

IDLE COMPONENT. Synonym for REACTIVE COMPONENT.

I.F. Abbreviation for INTERMEDIATE FREQUENCY.

IGNITION INTERFERENCE. Interference of an impulsive type caused by radiation from the ignition systems of petrol engines. It is generally most severe in the very-high-frequency wave band, and is the most widespread form of interference to which television is subject. The most effective cure is suppression at the source by means of screening the ignition leads and fitting suppressor resistors in series with the sparking plugs. The effects in receivers can be mitigated by limiter circuits.

IGNITRON. Mercury-arc rectifier in which an ignition electrode is used to maintain the flow of current every half-cycle of alternation of the wave that is applied. The term, of American origin, describes a mercury-arc rectifier which, like the mercury-vapour (hot-cathode) rectifier, possesses an automatic starting facility and yet has the heavy current capacity of an ordinary arc rectifier. In the ordinary mercury-arc rectifier, a considerable process has to be gone through before the arc is struck and the device, therefore, ready to function. In the Ignitron, however, rectification begins at once.

The Ignitron is a mercury-arc tube having a mercury pool in the bottom of an evacuated bulb and an anode above the pool. It also contains an igniting electrode which serves to strike the arc at a given period determined by the cycle of alternation of the applied current.

The igniting electrode is made of a suitable refractory material and makes contact with the mercury pool. A large current passes between this electrode and the mercury pool surface and this creates a small spark. This develops into an arc between anode and cathode if a suitable potential is applied to the anode at the time the spark is struck. Once the arc is established, the ignition circuit opens, so saving the power otherwise necessary to maintain the arc. See MERCURY-ARC RECTIFIER, MERCURY-VAPOUR (HOT-CATHODE) RECTIFIER.

IMAGE-ATTENUATION COEFFICIENT. Real part of the image-transfer constant of a network. This coefficient expresses the difference in level between the signals at the input and output terminals of a network terminated in its image impedance. See ATTENUATION COEFFICIENT, IMAGE IMPEDANCES, IMAGE-TRANSFER CONSTANT.

IMAGE DISSECTOR. Electron camera developed by Farnsworth. It uses a photo-electric cathode on which an image of the subject to be televised is focused. Each minute portion of the cathode emits electrons, the number being directly proportional to the amount of the light falling on it.

By a suitable electromagnetic field, the electrons from any point on the cathode can be made to focus at a point. This point is a hole in the anode which is kept at high potential with respect to the cathode. By means of deflector coils situated outside the tube, the electron image focused on the hole in the anode is made to move up and down and across the tube, so that the image is made to scan the hole. The effect is of scanning the cathode in a regular sequence of lines.

The electrons passing through the hole in the anode can then be collected and made to produce a potential difference which varies in accordance with the amount of light falling on various parts of the original image.

The scanning is accomplished by applying to one set of deflector coils (Fig. 1) a saw-tooth current wave having a frequency equal to the number of times per second the scene is to be scanned, that is, the frame frequency, and to the other coils a saw-tooth current wave having a frequency equal to the line frequency.

IMAGE-DISSECTOR MULTIPLIER. Device incorporated into the Farnsworth image dissector (see IMAGE DISSECTOR) which provides amplification by electron multiplication. The anode of the image dissector is replaced by a second cathode having a small hole in it, as shown in Fig. 2. Behind the second cathode is a cylindrical anode, and behind this is a third cathode coated with some electron-emitting material, such as caesium.

Electrons given off by the first cathode and accelerated by the anode fly through the hole in the second cathode as the scanning process is carried out. After passing the anode they strike the third cathode, where secondary electrons are given off. These are attracted by the anode and, since an alternating potential is applied between the third and second cathodes, the electrons fly past the anode and strike the back of the second cathode. Again secondary electrons are released, and they fly back to the third cathode, releasing still more secondaries.

Thus the few electrons escaping through the hole in the second cathode from the camera section give rise to a comparatively large stream of electrons bouncing back and forth between the second and third cathodes.

Two methods of stopping the process can be used. One is to make use of the drift of electrons to the anode, and to control the rate of drift by a guiding magnetic field set up by the solenoid

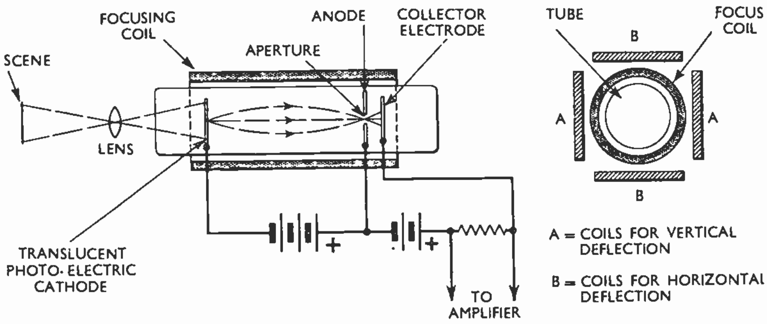
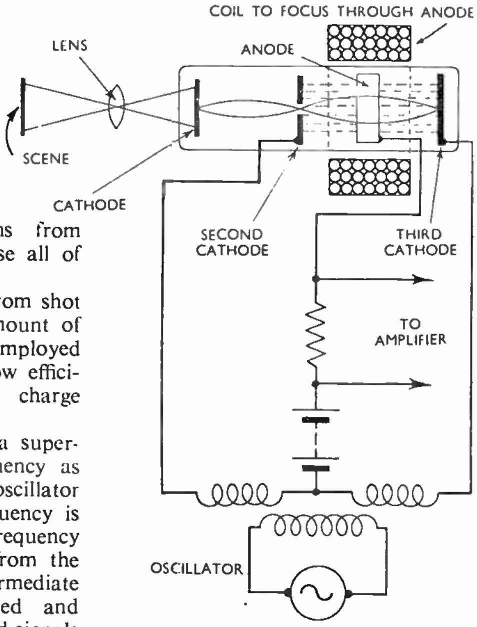


Fig. 1. Diagrammatic section and plan of the Farnsworth image-dissector tube, showing the coils used for magnetic scanning of the electron image.

Fig. 2. Simplified circuit arrangements of the image-dissector multiplier; the scanning and focusing coils of the dissector section have been omitted.



round the anode. The other is to apply a quenching frequency which will stop the oscillation of electrons from cathode to cathode and cause all of them to go to the anode.

Such a multiplier suffers from shot effect and this limits the amount of multiplication that can be employed in practice. The tube has low efficiency because there is no charge storage.

IMAGE FREQUENCY. In a superheterodyne receiver, a frequency as much above (or below) the oscillator frequency as the signal frequency is below (or above) it. Image-frequency signals produce an output from the frequency-changer at the intermediate frequency, and are accepted and amplified as well as the wanted signals by the I.F. amplifier, thus causing interference or whistles in reception.

For this reason, signal-frequency circuits are designed to reject image-frequency signals as far as possible. See INTERMEDIATE-FREQUENCY AMPLIFIER, SECOND-CHANNEL INTERFERENCE, SUPERHETERODYNE RECEPTION.

IMAGE IMPEDANCES. Two impedances such that when one of them is connected across the appropriate pair of terminals of a four-terminal network, the other is represented by the other pair of terminals of the network. Fig. 3 shows a network with four terminals, that is, a quadripole. The two image impedances are 1,000 and 100 ohms because, if the 1,000 ohms is connected across the terminals 1 and 2, terminals 3 and 4 have an impedance of 100 ohms; and when the 100 ohms is connected across terminals 3 and 4, terminals 1 and 2 have an impedance of 1,000 ohms.

If the two image impedances are equal, their value is the characteristic impedance of the network. To avoid losses in joining filter sections, the impedances of the two sections where they are joined must be the same, and must vary in the same way with frequency. In many cases, the filter sections have different impedances at either end, and they must be joined appropriately on an image-impedance basis. See CHARACTERISTIC IMPEDANCE, FILTER, FILTER SECTION, ITERATIVE IMPEDANCE, QUADRIPOLE.

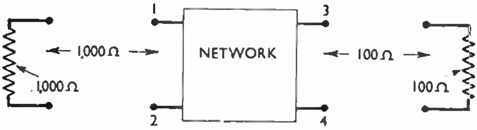


Fig. 3. Diagram of a quadripole which illustrates the example of image impedances described above.

IMAGE PHASE-CHANGE COEFFICIENT. Imaginary part of the image-transfer coefficient of a network. This coefficient expresses the difference in phase between the signals at the input and the output terminals of a network terminated in its image impedance. See IMAGE IMPEDANCES, IMAGE-TRANSFER COEFFICIENT, PHASE-CHANGE COEFFICIENT.

IMAGE RATIO. See SECOND-CHANNEL RATIO.

IMAGE-TRANSFER COEFFICIENT. Coefficient expressing the loss or gain in a network when it is terminated in its image impedance. Accurately expressed, it is one-half the natural logarithm of the vector ratio of the steady-state volt-amperes entering the network, to the volt-amperes leaving it. It is assumed that the network is terminated in its image impedance. See PROPAGATION COEFFICIENT.

IMAGE-TRANSFER CONSTANT. Synonym for IMAGE-TRANSFER COEFFICIENT.

IMPEDANCE. Measure of the total opposition to the flow of an alternating current round a circuit. Impedance comprises both reactance and resistance. But it is not simply the sum of the two quantities; it is the square root of the sum of their squares, thus, $Z = \sqrt{R^2 + X^2}$, where Z is the impedance, X the total reactance of the circuit, and R its resistance. The total reactance is, of course, the arithmetic difference of the inductive and capacitive reactances, thus, $Z = \sqrt{R^2 + (X_L - X_C)^2}$. It is at once apparent that there is here a special case in which $X_c = X_L$; the impedance then becomes simply the resistance. This is the case of the series resonant circuit (see TUNING).

Since both X_L and X_c are quantities into which frequency enters, it follows that it is meaningless to refer to the impedance of a circuit or component unless working frequency is specified.

Where alternating current is concerned it is the impedance which must be used in such calculations as finding the current in a given circuit; it will not suffice to apply Ohm's law to the voltage and resistance alone. Similarly, when determining the voltage drops across the individual components of a circuit carrying alternating current, it is their impedance which must be used, not simply their resistance as would be the case in a D.C. circuit. See REACTANCE, RESISTANCE.

IMPEDANCE COUPLING. See COMMON-IMPEDANCE COUPLING.

IMPULSE EXCITATION. Excitation of the grid of a valve in which flow of anode current is permitted for only a short part of each cycle.

IMPULSE FREQUENCY. Number of impulses per second in a train or group of regularly recurring impulses. See IMPULSE PERIOD, IMPULSE RATIO.

IMPULSE NOISE. Noise or interference having a relatively large peak value and short duration. If it cannot be prevented at the source, the most effective remedy is a limiter in conjunction with circuit design aimed at preserving the brevity of the wave form. See IGNITION INTERFERENCE.

IMPULSE PERIOD. Time period between the corresponding points of two successive impulses in a train or group of regularly recurring impulses. See IMPULSE FREQUENCY, IMPULSE RATIO.

IMPULSE RATIO. Ratio of the duration of an impulse to an impulse period. See IMPULSE FREQUENCY, IMPULSE PERIOD.

INCREMENTAL PERMEABILITY. Permeability of iron or other magnetic substance measured in terms of the additional flux produced by a small change in magnetizing force when the material is already magnetized by a steady polarizing current. The measurement is typically made by means of a small alternating current superimposed on a direct current already flowing in the magnetizing winding.

INDEPENDENT BEAT OSCILLATOR. Circuit used for beat reception in which a separate oscillator generates the waves to produce beating with the incoming signal. In some circuits, the valve which receives the signals also produces the beat oscillations to detect them, and this is called an autoheterodyne system. The term beat reception is preferred. See BEATING, BEAT RECEPTION.

INDEPENDENT DRIVE. Synonym for MASTER OSCILLATOR.

INDEPENDENT HETERODYNE. Synonym for INDEPENDENT BEAT OSCILLATOR.

INDIRECTLY HEATED CATHODE. Cathode, consisting of a cylinder coated externally with an oxide, which freely emits electrons when heated and embraces a coil which is heated by a current drawn from an external source. The oxide-coated cathode is insulated from the heater. The cylinder is made of thin sheet nickel and the emitting coating is spread over its surface. The heater coil, or wire, is of tungsten and is covered with some insulating material such as aluminium oxide. In general, it is inadvisable to let the cathode potential differ from the heater potential by more than 100 V, otherwise the insulation between cathode and heater may break down.

The indirectly heated cathode has several advantages; for instance, it is an equipotential cathode; the cathode potentials of a number of valves energized from the same heater supply may be different (see CATHODE BIAS); no elaborate arrangements are required to maintain mechanical rigidity between the hot and cold conditions are necessary with the finer wire-filament types of cathode.

On the other hand, the emission surface is more sensitive to bombardment by positive ions than the fine tungsten filament, so that the greater emission efficiency and other advantages of the indirectly heated cathode cannot be used in high-power valves. See CATHODE, CATHODE BIAS, EMISSION, FILAMENT.

INDIRECTLY HEATED VALVE. Valve in which the cathode is indirectly heated. See INDIRECTLY HEATED CATHODE.

INDIRECT RAY. Synonym for IONOSPHERIC RAY.

INDUCTANCE. Property of a circuit which causes it to oppose any change in the current flowing therein. Inductance is a quality possessed by all current paths, since it arises from the self-induction effect of the magnetic field which surrounds a conductor carrying a current. It is thus a product of the process of electromagnetic induction acting back into the circuit in which the originating current flows. A change in the current (and hence in the surrounding magnetic field) will not merely induce an e.m.f. in a neighbouring circuit, but it will induce one in the original circuit. Further, the voltages induced back into a circuit when the current alters are in such a direction as to oppose the change; when the current is falling the voltages induced by the shrinking magnetic field are in a direction which tends to maintain the current (see LENZ'S LAW).

This effect may be regarded as analogous to inertia in the mechanical world; there is a flywheel effect in an inductor which delays the rise of a current when the driving voltage is first applied, and correspondingly delays its decay when the voltage begins to fall. Thus, in an alternating-current circuit, the current wave lags behind the voltage wave; the phase-angle by which the current lags is determined by the amount of inductance in the circuit if there is resistance also, or by the preponderance of inductive effect if there is capacitance also. Capacitance, of course, causes the current to rise to its maximum *ahead* of the voltage maximum (see LAGGING LOAD, PHASE ANGLE).

When the current rises during the beginning of a half-cycle, energy is stored in the growing magnetic field around the conductor. When the current falls, the magnetic field collapses and in doing so induces a voltage which tends to maintain the current; thus the stored energy is returned to the circuit.

There is a magnetic field of force round any conductor of current, but it is relatively weak round a straight one; i.e. straight wires have a low inductance. The strength of the magnetic field is manifestly a measure of the inductance of the current path, so a unit for evaluating inductance could be expressed in terms of the field produced by unit current. The practical unit is, however, defined in a somewhat more direct manner (see HENRY).

Strong magnetic fields of force are produced by coiling up the conductor to form a winding; practical inductors are nearly always wound in this manner. The term inductor is now generally used in preference to the older term "inductance," which sometimes led to confusion between the property itself and the device which possessed it.

One type of inductor is a single-layer winding of wire on a hollow tube, and such components are often used in radio work where space permits. A more compact winding, in some multilayer form, enables the same amount of wire to produce still more inductance and at the same time reduces the space required; inductors of this kind are also used.

Anything which increases the intensity of the magnetic field of force will, by definition, increase the inductance value. A core with a permeability higher than that of air will obviously do this, and for low-frequency purposes an iron core is generally used; it is usually necessary to laminate it to reduce eddy currents, and the laminated iron core is practically universal in all large-value inductors for low and audio frequencies (see EDDY CURRENT, PERMEABILITY).

At high frequencies, eddy-current losses become prohibitive and iron cores of the type commonly used at audio frequencies are not used at radio frequencies. High-permeability cores of a certain type are nevertheless used in many modern R.F. inductors; these cores consist of extremely finely divided iron in the form of dust, usually embedded for mechanical convenience (and to insulate the individual particles) in a solid medium of wax or plastic material.

Properly applied, the principle of the high-permeability core leads to a more efficient inductor even at quite high frequencies; it enables the desired amount of inductance to be obtained from a smaller number of turns in the winding; and the shorter length of wire used results, other things being equal, in a lower resistance. Dust-core inductors are therefore widely used in radio receivers; they have the secondary advantages that slight corrections of inductance value for matching purposes can be made by adjustment of the position of the core within the winding.

Inductance is required for many purposes in electrical and radio work. High-value inductors, colloquially known as "chokes," are used to provide a barrier against alternating or oscillating currents and to divert them from some part of a circuit where they are not wanted. For radio-frequency purposes, the inductances are usually less than a tenth of a henry; the inductors are somewhat similar in construction to the inductors used in tuned circuits.

Chokes for low-frequency purposes have inductance values of the order of, say, 5–100 H. They are usually wound on closed iron cores similar to those of transformers, except that a small air gap is usually left in the magnetic circuit; this air gap ensures greater constancy of inductance when the choke is required to carry varying amounts of direct current and, at the same time, to act as a barrier to alternating currents. A typical application is in a smoothing filter (see SMOOTHING CIRCUIT).

One of the most important uses of inductance is found in the tuned circuits of radio apparatus. Here, a precise value of inductance is needed in conjunction with a definite amount

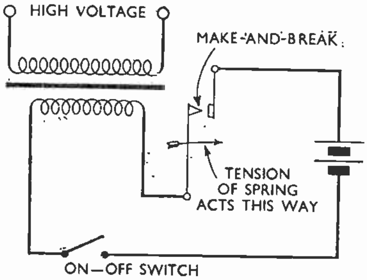


Fig. 4. Operating principle of the induction coil. When current flows in the primary circuit, the magnetized transformer core opens the make-and-break contacts; current thereupon ceases to flow in the primary, the points are closed by the spring, and so on. These sudden changes in primary current cause high voltages to be induced in the secondary winding.

of capacitance to tune to a given frequency; inductors for this purpose are, therefore, made to a particular standard when (as in all modern receivers) they are tuned by the various sections of a ganged tuning capacitor (see GANGING. MATCHING).

The amount of inductance required for each wave band in a receiver is that which will resonate at a wavelength just below the bottom limit of the band when placed in parallel with the minimum capacitance value of the variable capacitor, plus such stray capacitance as there may be in the circuit. This is a matter for empirical determination rather than calculation, but for approximate results the usual wavelength formula can be used to find the amount of inductance needed for resonance. See TUNING.

INDUCTANCE COIL. Synonym for FIXED INDUCTOR.

INDUCTANCE COUPLING. Synonym for INDUCTIVE COUPLING.

INDUCTION. Process of producing electrical or magnetic effects at a distance, without direct connexion between the electric current, electric charge or magnet which is producing the effect, and the circuit or body in which the effect is set up. See ELECTROMAGNETIC INDUCTION, ELECTROSTATICS.

INDUCTION COIL. Essentially a transformer having a make-and-break system, similar to that of an electric bell, in series with the primary. When a direct voltage is applied to the primary circuit (including the make-and-break and the primary coil of the transformer), high-voltage pulses are induced in the secondary coil.

In an induction coil the current is regularly interrupted by the make-and-break system. This produces a very large rate of change of flux in the secondary circuit and so a very high induced secondary voltage.

The differences between the induction coil and an ordinary transformer are:

1. In the transformer, the primary is energized by an alternating current, but the primary of the induction coil is fed with a suddenly interrupted current supplied from a direct voltage source.

2. The secondary voltage of an ordinary transformer used in a normal way is sinusoidal, but the secondary voltage of an induction coil is "peaky," and these peaks may have voltages of the order of a thousand, ten thousand, or even a hundred thousand volts, although the source of primary D.C. power has a low voltage.

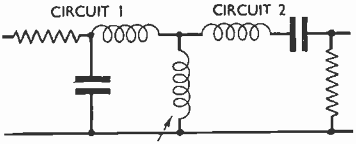
Fig. 4 illustrates the principle described. The induction coil was widely used in the early days of radio communication to produce the power for spark senders of moderate power (see SPARK SENDER, SPARK SENDING SYSTEM).

INDUCTIVE. Having the quality of inductance, whether distributed over a circuit or localized in a component part. See INDUCTANCE.

INDUCTIVE ATTENUATOR. Attenuator for use at radio frequencies consisting of inductive elements. See ATTENUATOR.

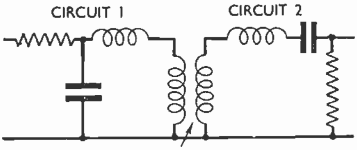
INDUCTIVE CAPACITY. Synonym for PERMITTIVITY.

INDUCTIVE COUPLING. Coupling of two circuits, either by a common impedance which is predominantly inductive, or by mutual inductance. Fig. 5 shows two circuits, one with common-impedance coupling by an inductive reactance, and the other coupled by mutual inductance. See COMMON-IMPEDANCE COUPLING, COUPLED CIRCUIT, COUPLING.



COUPLING BY AN INDUCTOR

(a)



COUPLING BY MUTUAL INDUCTANCE

(b)

Fig. 5. Two kinds of inductive coupling of circuits are shown: (*a*) by a common impedance in the form of an inductor, and (*b*) by mutual inductance.

INDUCTIVE FEEDBACK. Feedback of energy from one stage of a valve amplifier to another when they are coupled inductively. The coupling may be provided purposely to give feedback, or it may be caused by the close proximity or relative positions of certain components, producing unwanted positive feedback and, possibly, instability.

INDUCTIVE-FEEDBACK OSCILLATOR. Any valve oscillator in which the feedback of power from anode to grid circuits takes place only by an inductive path. An example is the Hartley oscillator.

INDUCTIVE LOAD. Synonym for LAGGING LOAD.

INDUCTIVE-OUTPUT VALVE. Valve in which an electrode is placed in the proximity of the electron stream, but which does not collect electrons. Changes of density of the electrons in the electron stream induce voltages on this electrode. The valve is designed to be used as an amplifier of waves of very high frequency (hundreds or thousands of megacycles per second). It has not found much practical application, being inferior in performance to special triodes, cavity magnetrons, Klystrons and so forth. See OSCILLATOR.

INDUCTIVE REACTION. Synonym for INDUCTIVE FEEDBACK.

INDUCTIVE RESISTOR. Wire-wound resistor having appreciable self-inductance, either by intent, or because of lack of care in design. See FIXED RESISTOR.

INDUCTIVE RETROACTION. Synonym for INDUCTIVE FEEDBACK.

INDUCTOR. Device capable of storing electromagnetic energy, and used primarily because of its property of inductance, or of inductive reactance when used in an alternating-current circuit. Its essential parts are a coil of one or more turns of insulated conductor wound on an insulating former or spool (which is usually hollow) and enclosing a core. The core may be of magnetic material, such as iron or an iron alloy, or it may be non-magnetic, such as is air or the insulating material of a solid former.

The inductance of such a coil is given by $L = \left(\frac{4\pi n^2}{S}\right) 10^{-9}$ henrys, where n is the number of turns of wire and S is the reluctance of the magnetic circuit.

In a high-permeability *iron-cored inductor*, in which the magnetic flux is confined to the core, the reluctance depends solely on the geometry of the core (not the coil) and on its permeability. It is given by the formula $S = \frac{l}{A\mu}$, where l is the mean length of the magnetic circuit (in cm.), A is the cross-sectional area (in sq. cm.) and μ is the magnetic permeability of the material.

If there is a small air-gap in the core (a normal method of reducing the iron losses, or the effect of too high a current, or of a superimposed direct current upon the value of the inductance), then the total reluctance is the sum of the separate reluctances: $S = S_i + S_a$, where $S = \frac{l_i}{A\mu}$ and $S_a = \frac{l_a}{A}$. Here, l_i and l_a represent the mean length of the iron and air parts of the magnetic circuit respectively (the value of μ for air is 1). At the low values of flux density used in audio-frequency inductors, the effective permeability of silicon-iron laminations is about 500 and of nickel-iron laminations about 2,000.

The above formulae do not apply to dust-cored inductors because sub-division of the magnetic material lowers the effective permeability considerably.

In an *air-cored inductor*, except in the case of a toroidal-wound inductor, the magnetic flux is not confined to a core of known dimensions. For this reason it is not possible to state a general formula for inductance which is of an exact nature. Reliance has to be placed on formulae derived experimentally; although various formulae are sometimes given which depend upon the shape of the coil, the number of layers of wire and the method of winding.

The accompanying diagram (Fig. 6) gives a formula for the low-frequency inductance of a single-layer winding of circular wires on a cylindrical former, and which is approximately true for multiple-layer and wave-wound inductors. The effective inductance at radio frequencies is modified by the self-capacitance of the coil and to a small extent by its increased resistance. See FIXED INDUCTOR, VARIABLE INDUCTOR.

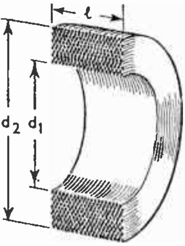
L = k d n² MICROHENRYS

WHERE n = TOTAL NUMBER OF TURNS

d = MEAN DIAMETER IN cm.

$= \frac{d_1 + d_2}{2}$

k = CONSTANT DEPENDENT UPON RATIO $\frac{d}{l}$ GIVEN BELOW



$\frac{d}{l}$	0·1	0·2	0·5	1·0	2·0	5·0	10·0
k	0·0009	0·0018	0·0040	0·0068	0·0104	0·0158	0·0200

Fig. 6. Formula for low-frequency inductance of a single-layer winding; it is approximately true for multi-layer and wave-wound inductors.

INDUCTOR LOUDSPEAKER. Moving-iron loudspeaker, the armature of which moves like a piston between two pairs of magnetic poles. This gives some freedom of movement to both armature and cone, giving good low-frequency response.

INDUCTOR MODULATION. System of non-linear modulation in which the sources of carrier and modulating wave are connected in series and applied to an inductor. The amplitude of the wave produced by adding the two waves varies, and the inductor offers an impedance which varies with the varying amplitude of the sum of the carrier and modulating waves. This resultant wave is, therefore, distorted, and contains the modulated wave, which is selected by a filter.

If the inductor has two windings, linear modulation is possible; the modulating wave is applied to one winding and the carrier wave to another. The variable magnetization of the core caused by the modulating wave causes the carrier wave to be modulated. Both methods are obsolescent. See LINEAR MODULATION, MAGNETIC MODULATION, NON-LINEAR MODULATION.

INERT CELL. Cell containing all the components and ingredients necessary for the generation of an e.m.f. except the water required to actuate the electrolyte. It is similar in construction to a dry cell of the Leclanché type and, while inert, it can be stored indefinitely without deterioration. See VOLTAIC CELL.

INFINITE ATTENUATION. Property of a device which, when a voltage is applied to its input terminals, produces no output at all at the output terminals. A "null network" gives infinite attenuation. The term is used, in connexion with filters, to specify a frequency at which infinite attenuation would be produced if the inductors and capacitors forming the filter arms had zero loss. See FREQUENCY OF INFINITE ATTENUATION, NULL NETWORK.

INFINITE-IMPEDANCE DETECTION. Detection by an anode-bend detector with 100 per cent negative feedback. The circuit of an infinite-impedance detector is given in Fig. 7; it consists of a triode with the load connected in the cathode circuit, the output signal being developed between cathode and H.T. negative. Thus the cathode resistor acts as anode load and also provides grid bias, and best results are usually obtained with a value of the order of 50,000 ohms. This is quite a suitable value for an anode load, but is very high for a cathode-bias resistor; thus the valve operates with a very great negative bias and nearly at anode-current cut-off—correct conditions for an anode bend detector.

The capacitor in parallel with the cathode resistor is small, usually about 100 pF, and performs the same function as the capacitor in a diode detector. It is charged-up on positive peaks of the applied carrier and approximately trebles the output voltage.

The capacitor is too small to decouple the cathode resistor at audio frequencies, and the valve thus behaves as a cathode follower at these frequencies, giving less than unity gain. The circuit is, in fact, sometimes known as a cathode-follower detector. The components R_2C_2 are for R.F. filtering and perform no essential part in the detection process.

The input impedance of a cathode-follower detector is very high (hence the name infinite-impedance) and, under certain conditions, may even be negative; thus there is very little damping of the initial tuned circuit, and the Q-factor may possibly be improved. This low damping is the chief attraction of the infinite-impedance detector; in all other properties it is very similar to the diode detector.

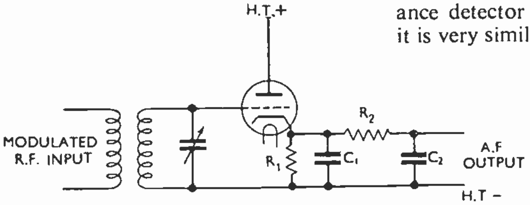


Fig. 7. Circuit of the infinite-impedance detector sometimes referred to as a cathode-follower detector.

INFINITE LINE. Uniform transmission line of infinite length, or of such a length that its sending-end impedance is substantially the same as if the line were of infinite length. If a line is short-circuited at a point near the sending end, the sending-end impedance is changed. If the line is infinitely long and its receiving end is short-circuited, there is no change in sending-end impedance because no voltage appears at the receiving end.

Thus a very long line gives so much attenuation that substantially no change in sending-end impedance would be noticed if the receiving end were short-circuited; the very long line, although of finite length, behaves as if it were an infinitely long line. The length of any line which behaves like an infinitely long line is determined by the electrical characteristics of the line. Thus, of any given line having a length greater than a specified value, it can be said that it is, in effect, an infinite line.

The characteristic impedance of a network or line is equal to the square root of the product of the sending-end impedances when the line is short-circuited and open-circuited respectively at its receiving end. Now the sending-end impedance of an infinite line is the same whether the receiving end is short-circuited or open-circuited. Thus the characteristic impedance of an infinite line is given by its actual impedance. See ARTIFICIAL LINE, CHARACTERISTIC IMPEDANCE, TRANSMISSION LINE.

INFRADYNE. Receiver employing the basic principle of the superheterodyne, but differing in that the intermediate frequency is *higher* than the signal frequency. Such a receiver does not possess the normal superheterodyne receiver's advantage of increased gain and stability in the I.F. amplifier stage, but it can be made to yield great selectivity. See SUPERHETERODYNE RECEPTION.

IN PHASE. Condition in which two currents or voltages, or a current and a voltage, alternate in perfect synchronism, passing through their maximum values at the same instant and their zero values at the same instant. That part of the current wave which is in step with the voltage, in an alternating circuit whose power factor is less than unity, is sometimes called the in-phase current.

IN-PHASE COMPONENT. Alternating current or voltage which is in perfect synchronism (i.e. in phase) with the reference component. See IN PHASE, PHASE-ANGLE, REACTIVE COMPONENT.

INPUT CAPACITANCE, IMPEDANCE, INDUCTANCE, RESISTANCE. Capacitance, impedance, inductance or resistance measured between the input terminals of a network, line, apparatus or any electrical device. See ELECTRODE IMPEDANCE, INTER-ELECTRODE CAPACITANCE.

INPUT CAPACITY. Term sometimes incorrectly used instead of INPUT CAPACITANCE.

INPUT IMPEDANCE. See INPUT CAPACITANCE (ETC.).

INPUT INDUCTANCE. See INPUT CAPACITANCE (ETC.).

INPUT RESISTANCE. See INPUT CAPACITANCE (ETC.).

INPUT TRANSFORMER. Transformer of which the secondary winding is connected across the input terminals of any network, line, apparatus or electrical device. The primary of the transformer is supplied with power which energizes the input terminals. See TRANSFORMER.

INPUT VALVE. Initial stage in any chain of valves in an amplifier or complete receiver; the valve, that is, to which the input is applied.

INPUT VOLTAGE. Voltage developed across the input terminals of any network, line, apparatus or electrical device.

INSERTION GAIN. Gain in voltage or current due to the connexion of a passive network between the output terminals of a generator and a load; or the gain in power due to the connexion of an amplifier between the output terminals of a generator and a load. The term is seldom used in connexion with amplifiers, the phrase "gain of an amplifier" being preferred. It should be noted that insertion gain in a passive network cannot represent a gain of power and so cannot be expressed in decibels.

In Fig. 8 it is assumed that the generator has an internal impedance made up of resistance and inductance (see INTERNAL IMPEDANCE). By connecting the generator to the load, a certain current in the load is produced. However, if a capacitor, having a reactance equal to the inductive reactance of the generator, is inserted between the output terminals of the

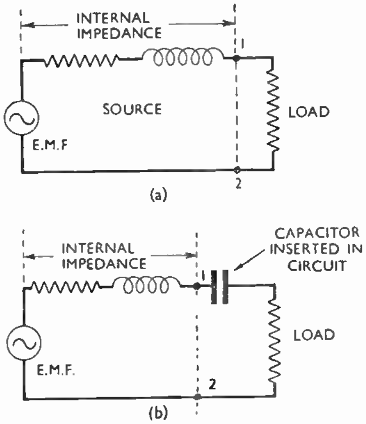


Fig. 8. A greater current flows in the load of circuit (*b*) than in that of (*a*), and the gain in power due to the inclusion of a suitable capacitor is an example of insertion gain.

generator and the load, the load current increases. This is because the two reactances cancel as in a series-resonant circuit, leaving a purely resistive circuit. There is thus a gain of power due to the insertion of the capacitor. See CONJUGATE IMPEDANCE, INSERTION LOSS, MATCHING.

INSERTION LOSS. Loss of power due to the connexion of a passive network or other device between the output terminals of a generator and the load. There may be apparatus in the circuit between the point of insertion and the generator, and between the point of insertion and the load, but the insertion loss is the power lost between the input and output terminals of the device causing the loss. The loss of power is expressed in decibels.

If a filter section, transformer, or resistance pad is inserted between the output of a generator and a load (Fig. 9), less power appears at the output of the device inserted in the circuit than is applied to the input. This loss is called the insertion loss. Insertion loss varies with frequency. The performance of transformers and filters is often expressed in terms of their insertion loss expressed in decibels. See DECIBEL, MATCHING.

INSTANTANEOUS FREQUENCY. Rate of change of phase of a wave of any shape divided by 2π. See PHASE.

INSTANTANEOUS VALUE. Value, at a particular instant of time, of any quantity which varies with time. For example, the sine graph (Fig. 10) shows the variation of voltage with time; but it might be desirable to express the value of the voltage at times t_1, t_2, t_3, and so on. These values,

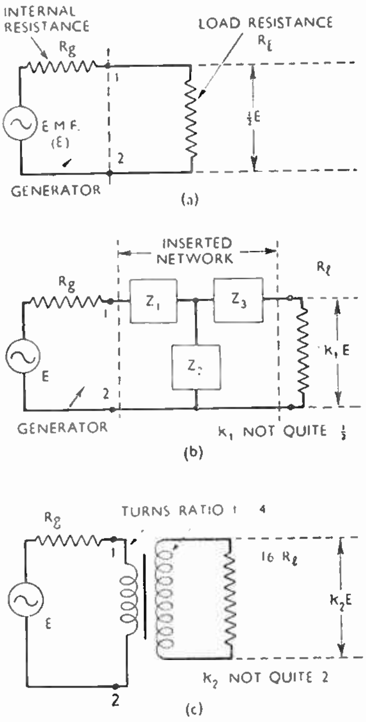


Fig. 9. Loss of power resulting from the insertion in circuit (*a*) of a network (*b*) or a transformer (*c*). It is assumed that $R_l = R_g$; the extent by which k_1 is less than ½ in (*b*) and by which k_2 is less than 2 in (*c*) is a measure of the insertion loss that is produced.

which are maintained for an infinitely short space of time, are instantaneous values. See SINE GRAPH.

INSTRUMENT. Any small piece of apparatus that is complete in itself, such as a microphone or pick-up.

INSTRUMENTAL ERROR. Error due to defects in design and/or construction in direction-finding equipment; this error may or may not include polarization error.

INSTRUMENT RECTIFIER. Small metal rectifier which, when incorporated with a D.C. instrument, makes it possible for that instrument to function on A.C. It is commonly used in meter circuits, when a moving-coil meter is required to measure alternating currents or voltages, as illustrated in Fig. 11.

INSULANCE. Synonym for INSULATION RESISTANCE. The term is also associated with liquid and solid capacitor dielectrics as the numerical product (in ohm-farads) of insulation resistance and capacitance.

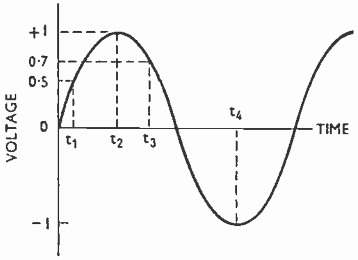


Fig. 10. Examples of instantaneous values at t_1, t_2, etc., of a voltage continually varying (alternating) in accordance with the sine graph.

INSULATION. Electrical isolation of conductors by non-conducting substances. In the earliest experiments with electricity, it was discovered that some materials, notably metals, allowed free passage of electric currents, while others, such as glass and rubber, did not. The two types of materials were called conductors and insulators respectively.

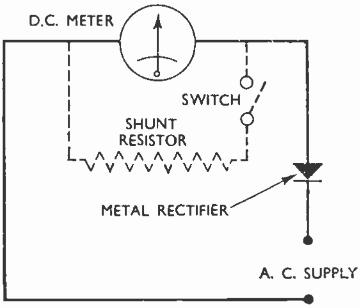


Fig. 11. Instrument rectifier connected in series with a moving-coil milliammeter for purposes of A.C. measurement. The shunt resistor is used when the current measured exceeds the capacity of the meter.

It was found that, to electrify a conductor, it was necessary to interpose an insulator between the conductor and earth; for example, if the conductor were held in the hand, it could not be electrified, for the charge leaked to earth through the body of the experimenter. These early experiments also proved that air was an insulator, for, so long as there was no physical connexion between the conductor and earth, the conductor could be electrically charged.

Insulators have the important property of relative permittivity. If, as in Fig. 12, two conductors are placed in space and given opposite electrical charges, an electric force exists between them. If the space is then filled by an

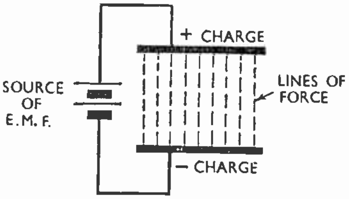


Fig. 12. Lines of force between two oppositely charged conductors. If the space (means of insulation) between the conductors is a vacuum, the permittivity is unity; if air, it is 1·006.

insulator other than air, the strength of the force changes. When this other insulator is a vacuum, the permittivity is said to be 1. Therefore, the relative permittivity of all other insulators is expressed in relation to permittivity in vacuo.

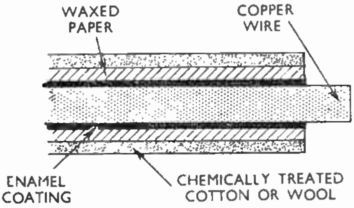


Fig. 13. Section through a telephone wire showing the insulation. Two such wires form a pair; usually, a cable contains a number of pairs.

Relative permittivity is sometimes called dielectric constant or specific inductive capacity. The higher the relative permittivity, the greater is the insulating efficiency of an insulator. Typical examples are: air 1·006, ebonite 2·8, shellac 3·5, mica 6·5 and porcelain 4·4 to 6·8.

Obviously, the voltage which an insulator will withstand before breaking down depends upon its insulating efficiency and hence upon its relative permittivity. Thus, where high voltages are concerned, materials having high relative permittivity must be used.

In the choice of insulating material for a specific purpose, consideration must be given to the mechanical stress as well as the electrical pressure to which the insulator will be subjected. It is because of this that porcelain is used for insulating electric power pylons and radio-sender masts. With capacitors, in which there is little mechanical stress, the insulating material used as a dielectric may be of paper or mica.

In the insulation of communication cables, due regard must be paid to possible chemical action between the conducting and insulating materials. The conductor is almost invariably copper; if this is insulated with rubber, the conductor must be tinned or enamelled to prevent chemical action between the copper and the sulphur content of the rubber. If the insulation is of waxed paper or cotton, it is highly inflammable and is thus unsuitable for use where high temperatures prevail; but, because this form of insulation is the most convenient for telephone cables, it is used extensively and is rendered flame-proof by chemical treatment, or by covering the insulator with non-inflammable material (Fig. 13).

In the construction of inductors or transformers for radio-engineering purposes, it is frequently necessary to incorporate a large number of turns of insulated wire in a small space; this precludes rubber or cotton insulation, and enamelled wire is therefore used.

In recent years, the use of plastic insulating materials has been widely adopted (see PLASTICS). These have the advantage of lightness and flexibility, and production costs are low.

Insulators used for high-power radio senders have to withstand exceedingly high voltages. To guard against the possibility of breakdown, they are tested, before installation, at voltages greatly in excess of their working voltages. Such tests involve highly

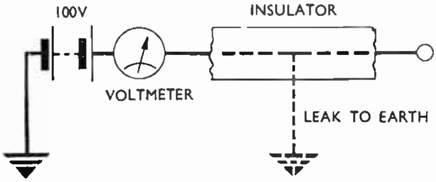


Fig. 14. In testing the insulation resistance of an insulated conductor in contact with earth, one side of the battery is earthed. The voltmeter indicates the battery voltage less the voltage drop across the leak.

complicated laboratory apparatus; voltages of a million, or even more, are applied across the insulator. The tests are applied gradually, the voltage being stepped up until the breakdown voltage is found. Comparison between the breakdown and working voltages indicates the margin of safety available with a given type of insulator.

The insulation efficiency of an insulated conductor can be obtained by measuring the insulation resistance (see INSULATION RESISTANCE). The test is a simple application of Ohm's law. Fig. 14 shows an insulated conductor, the insulation being in contact with earth. A battery and voltmeter are placed in series with one arm of the conductor and earth, the other arm of the conductor being open-circuited. The insulation resistance R can be obtained from $R = V/I$, where V is the voltage-drop across the leak and I is the meter current.

For example, suppose the test voltage to be 100 and the meter

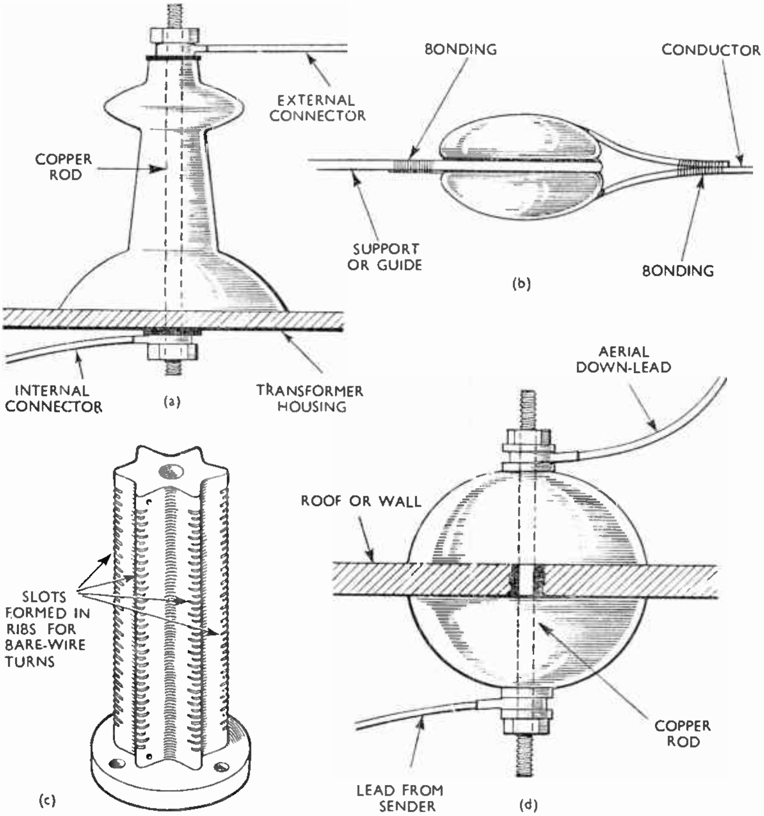


Fig. 15. The forms of insulator shown are (*a*) pillar-type porcelain insulator, frequently used with high-voltage transformers; (*b*) egg-type insulator, of porcelain or earthenware, used for aerials; (c) ribbed coil-former, which may be of ebonite, porcelain or plastics, for tuning inductors in receivers, and (*d*) dome-type porcelain insulator which is used between a sender and the aerial.

resistance to be 1,000 ohms per volt; the meter current will obviously be $\frac{100}{100 \times 1{,}000} = 0{\cdot}001$ amp.

Suppose that, on test, the meter reads 60 volts. This indicates a voltage drop of 40 and, applying the formula, the insulation resistance will be $\frac{40}{0{\cdot}001} = 40{,}000$ ohms.

It may seem that an ammeter would be more suitable for the test described, but a little thought will show that such a meter would have to be capable of carrying heavy currents in the event of a complete breakdown in insulation, whereas, if only a low test voltage were used, an insulation resistance of several thousand ohms would not cause a deflection on the meter.

In practice, the bridge tester is used for insulation tests (see BRIDGE MEGGER TESTER), such an instrument incorporating a hand generator of some 500 volts, and a meter which is calibrated in ohms.

INSULATION RESISTANCE. Resistance between two conductors, or a conductor and earth when separated by insulating material only.

INSULATOR. Any substance or body which offers high resistance to the passage of electric current. By reason of this high resistance, an insulator may be used to insulate a conductor from earth or from another conductor (see INSULATION).

Some typical examples are shown in Fig. 15; the first (a) being a type of insulator commonly used with high-voltage transformers. Such insulators are tested before use to ensure that they will withstand working voltages considerably higher than those likely to be encountered in the system with which they are used.

Also shown (Fig. 15b) is a very common type of insulator used for aerial insulation. Its construction is such that it needs no independent support, but is held in position by the supporting cable and the conductor. Such insulators are used with both sending and receiving aerials, and also for breaking up mast-supporting stays to prevent these stays from resonating at a particular frequency.

An insulating former on which the tuning coils for receivers can be easily constructed is illustrated in Fig. 15c. If bare wire is used, the ribs of the former are slotted to prevent neighbouring turns from touching.

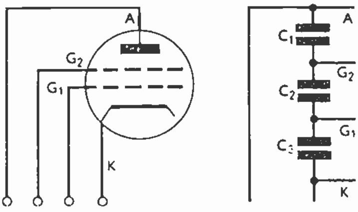
The typical bell, or dome-shaped, lead-in insulator (Fig. 15d), is commonly used at radio sending stations. The domes are hollow and their mechanical construction is such as to withstand a strain considerably greater than the normal stress imposed by the aerial down-lead. Similarly, they are tested before use to ensure that they will withstand an electrical pressure considerably in excess of that to which they would normally be subjected.

INTELLIGIBILITY. Percentage of words or sentences correctly received over a transmitting or reproducing system.

INTENSITY MODULATION. Synonym for AMPLITUDE MODULATION.

INTERCALATED SCANNING. Synonym for INTERLACED SCANNING.

INTER-ELECTRODE CAPACITANCE. Capacitance existing between any two electrodes of a valve under specified conditions (Fig. 16). Inter-electrode capacitance may have a



(a) (b)

Fig. 16. Inter-electrode capacitance in a tetrode (*a*) may be considered as being made up as at (*b*). Anode-to-control-grid capacitance (C_1 in series with C_2 is less than the anode-to-control-grid capacitance in a triode.

profound effect on the performance of valve amplifiers. This effect becomes more noticeable as the frequency of the waves amplified becomes greater see ELECTRODE CAPACITANCE, ELECTRODE IMPEDANCE, MILLER EFFECT).

The screen grid of the tetrode was introduced in order to minimize control-grid-to-anode capacitance (see TETRODE).

It is, in nearly all cases, desirable to minimize inter-electrode capacitance. The MINIATURE VALVE (q.v.) goes a long way in this respect, maintaining a required amplification factor in spite of a reduction in dimensions. See AMPLIFICATION, AMPLIFIER.

INTERFERENCE. Confusion of a desired signal by atmospherics, unwanted signals (jamming), or signals produced by electrical apparatus; in other words, all unwanted voltages at the input of a receiver, as distinct from set noise, which originates in the receiver.

The effects of unwanted signals depend on the type of interfering signal, and on its strength and frequency relative to the desired signal being received. Type A0 waves give audible beat interference when the difference in frequency is sufficiently low, unless the interference is so strong as to paralyse or swamp the detector.

When the frequency difference is supersonic, type A0 waves of sufficient strength may reduce ability to extract the wanted modulation frequency by sweeping the detector to cut-off in one polarity and to a relatively linear part of its characteristic in the other. It is as if the modulation depth of the desired signal were reduced. Type A1 waves produce the same effects intermittently and, in addition, may cause key clicks.

Any interfering signals modulated at an audible frequency introduce that frequency clearly if the beat frequency is supersonic. Even if it is prevented, by selectivity in the later stages of a receiver, from intruding directly, it may sometimes be rendered audible by cross-modulation. If the beat frequency is audible, the character of the interfering modulation is generally masked or modified by the beat interference present at the same time.

In broadcast reception the commonest interference is between wanted and unwanted broadcast transmissions (type A3 waves), and may be present as intelligible interference, in which the modulation of the interfering station is reproduced; as beat interference, between the carrier waves, and as sideband interference, or "monkey chatter," in which a splashing or unintelligible chattering sound is caused by the sidebands of either station interfering with the sidebands and/or carrier wave of the other. What is heard of all these depends on the relative frequencies and the R.F. and A.F. selectivity of the receiver.

The term "interference" is sometimes used to refer only to the remaining types, as distinct from atmospherics and jamming. These are as varied in nature as the appliances causing them. Any change in electric current sets up a wave which includes components covering a band of frequencies depending on the suddenness of the change.

Theoretically, an instantaneous change covers an infinite frequency band. Any device in which there are more or less frequent sudden changes of current is, therefore, liable to interfere with radio reception, the interfering waves being transferred to neighbouring receivers by radiation or power lines, etc., or both.

Thus each operation of a switch or contact may cause a click, rotary machines with commutators set up a continuous singing or roaring sound, and other appliances are heard as buzzes, rustles, crackles, hisses and so on.

Although the interference is generally distributed fairly widely over the R.F. spectrum, it is usually strongest at the lowest frequencies, though it may be intensified at particular frequencies by resonance in the interfering appliance. Special cases, particularly troublesome on the higher frequencies, are diathermy and R.F.-heating sets, which have been known to cause interference at a range of thousands of miles.

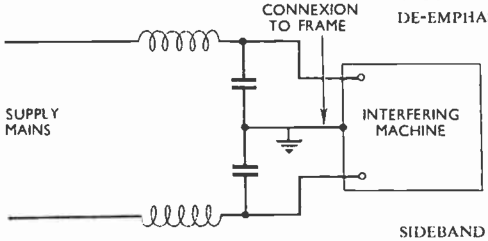


Fig. 17. Typical filter for suppressing interference caused by an electrical machine or appliance.

With regard to anti-interference methods, it may be said that, in general, it is desirable to limit the R.F. band width of the receiver to the minimum necessary for the desired signal at a sufficiently early stage to prevent cross-modulation. Beat interference on a fixed frequency within the reproduced A.F. band can be minimized by a sharply tuned filter. As the most audible interference is generally relatively high in frequency, it may be reduced by de-emphasis. It is also beneficial to increase the desired carrier wave relative to the sidebands by extreme selectivity, correcting the resulting progressive attenuation of the sidebands by tone control.

The best remedy for noise interference is suppression at the source, by-passing the interfering currents to earth by means of capacitors, and limiting or diverting them from undesired channels by series resistors or inductors. The only way to suppress diathermy and R.F. heating equipment is to operate it in a screened room. To prevent interference reaching the receiver via the mains a filter, such as that shown in Fig. 17, may be used. Interference coming via the aerial is more difficult to deal with, but the signal-to-noise ratio can often be greatly improved by installing an anti-interference aerial system.

Interference with television is due chiefly to ignition, diathermy, etc., and is severe if the equipment is not screened. Directional aerials may occasionally help, but the most useful remedy is to use limiters in both sound and vision channels. Interference on the vision channel is particularly undesirable because it mars the picture with spots and may upset the synchronization. See ANTI-INTERFERENCE AERIAL-SYSTEM, ATMOSPHERICS, DE-EMPHASIS, JAMMING, LIMITER, NOISE. SIDEBAND INTERFERENCE, SIGNAL-TO-NOISE RATIO.

INTERFERENCE NOISE. See INTERFERENCE.

INTERLACED SCANNING. Method of scanning, employed in television, in which the lines are not taken in numerical sequence. Thus, instead of scanning consecutive lines, such as 1, 2, 3, 4, 5, 6, etc. to the end, the lines are taken alternately, or two lines are missed after each one taken. In interlaced scanning, often referred to as interlacing, the picture is transmitted in two or three partly complete frames instead of one complete frame at a time. The result, to the eye, is that a greater number of pictures per second is being transmitted, with resultant reduction in flicker.

The rate of scanning is determined by two factors: the motion must be fast enough to appear continuous to the eye, and the whole field must be covered a sufficient number of times in a second to give the impression of continuous, flickerless movement. The number of complete pictures per second required to avoid flicker depends on the brightness of the picture; 25 per second are advisable when the picture is not very bright, and 50 when the picture is bright.

To avoid having to scan the complete picture 50 times in a second, and yet achieve the illusion that 50 pictures per second are being received, interlaced scanning is employed. If alternate lines are scanned, the eye is given the impression that the picture has been completely scanned when only half of it has been covered. This is because the lines are close together and alternate lines provide what is apparently a fully illuminated picture.

Thus, while the picture-frequency that has to be dealt with in the sender and receiver is only 25 per second, the benefit of a picture-frequency of 50 per second is obtained. This illusion is a valuable one technically. The sidebands that have to be dealt with by the sender and picked up and amplified by the receiver depend, for a given picture ratio, on two main factors, namely, the number of lines per picture and the number of frames per second (see HIGH-DEFINITION TELEVISION).

Now consider the two following cases: 405 lines per picture at 25 pictures per second, and 405 lines at 50 per second. The former is obviously preferable since it requires the smaller band width. The definition of the two schemes is the same; that is decided by the 405 lines. The flicker, however, is different, that of 50 pictures being less noticeable.

To attempt to obtain the benefits of both reduced flicker (50 pictures) and minimum band width (25 pictures), the interlacing system is used. We obtain our 50 pictures so far as the eye is concerned, and, in fact, we retain our 25 complete pictures and so reduce the band width. The lines are transmitted in frames of only 202½ lines each, 50 times per second.

Triple interlacing (taking every third line) has also been tried with success, and this provides the equivalent of 75 pictures a second so far as the eye can judge. But there is a limit to this interlacing since, if too many lines are skipped each time, the eye begins to realize that something is wrong, and the effect of constant illumination is lost.

INTERMEDIATE CIRCUIT. Synonym for INTERMEDIATE-FREQUENCY AMPLIFIER.

INTERMEDIATE FREQUENCY. Frequency to which incoming signals are converted (usually for further amplification) in a superheterodyne receiver.

INTERMEDIATE-FREQUENCY AMPLIFIER. That portion of a superheterodyne receiver devoted to amplification of the signals after frequency-changing and before detection.

INTERMEDIATE-FREQUENCY INTERFERENCE. Interference by signals at the intermediate frequency, which by-pass the pre-selector and frequency-changer and are picked up by the I.F. amplifier via stray coupling (see SUPERHETERODYNE RECEPTION). The cure is adequate screening and a wave-trap in the aerial lead. See SECOND-CHANNEL INTERFERENCE.

INTERMEDIATE-FREQUENCY OSCILLATOR. Oscillator beating with the intermediate-frequency signals in a superheterodyne receiver, to permit reception of type A1 signals. See BEAT RECEPTION, SUPERHETERODYNE RECEPTION.

INTERMEDIATE-FREQUENCY TRANSFORMER. Inter-valve coupling device used in the intermediate-frequency amplifier of a superheterodyne receiver. It usually has an iron-dust core, and is enclosed in a screening box.

INTERMEDIATE WAVE. See DECAMETRIC WAVE, HECTOMETRIC WAVE.

INTERMODULATION. Production of new, and usually unwanted, frequencies by the combination or interaction of other frequencies. See INTERMODULATION DISTORTION.

INTERMODULATION DISTORTION. Form of non-linear distortion which takes place when signals of two or more frequencies are present together. For example, if signals of

200 c/s and 900 c/s are being amplified, and the 200 c/s is strong enough to overload the amplifier, it modulates the 900 c/s signal, creating new frequencies of 900±200, 900±400, etc. (see MODULATION, SIDEBAND).

In the reproduction of music, these spurious frequencies are usually discordant and are more unpleasantly noticeable than the harmonics produced at the same time. Unfortunately they are more difficult to measure. See HARMONIC DISTORTION, NON-LINEAR DISTORTION.

INTERNAL ANODE-IMPEDANCE. See ANODE SLOPE-RESISTANCE, INTERNAL IMPEDANCE.

INTERNAL CAPACITANCE. Capacitance value of the capacitive reactance forming part of the internal impedance of a source of electric power. See INTERNAL IMPEDANCE.

INTERNAL IMPEDANCE. Impedance of a source of electric power assumed to exist between an e.m.f. and the output terminals of the generator. It is obvious that any D.C. source must have internal resistance. If, for example, a dry cell is short-circuited, the current is, say, 5 amp. If the open-circuit voltage is, say, 1·5 volts, the e.m.f. acts on a resistance of $\frac{1\cdot5}{5} = 0\cdot3$; the internal resistance is 0·3 ohm. If the short-circuit current of a dynamo is 4,000 amp. and its open-circuit voltage 400 V, its internal resistance is $\frac{400}{4{,}000} = 0\cdot1$ ohm.

A more practical way of determining internal resistance is to connect across the output terminals a resistance of such value that the generator volts are halved. This resistance then equals the internal resistance of the source, because the drop of volts is the same across internal and external resistance, and current is the same in each.

A source of alternating power may have internal reactance; Fig. 18 shows a generator with internal reactance; if an external reactance of opposite sign to the internal reactance be adjusted until the current is a maximum, the two reactances are equal. This is because a series-tuned resonant circuit is set up. Knowing the value of the *external* reactance and its type (capacitive or inductive) to produce maximum current gives the value of the *internal* reactance and its type; the external and internal reactances must be of opposite types to produce resonance. See MATCHING, MISMATCHING FACTOR, REACTANCE, RESISTANCE, RESONANT CIRCUIT.

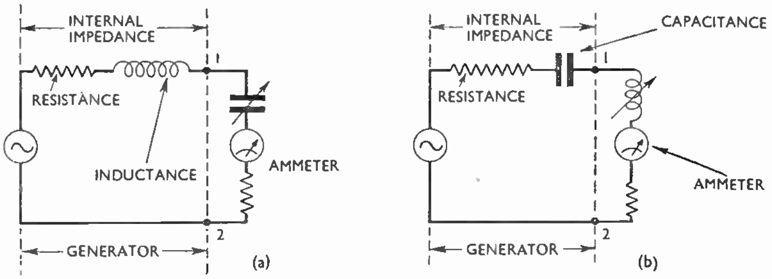


Fig. 18. To measure the internal impedance of a generator when this is inductive (*a*), a calibrated variable capacitor in the external circuit is adjusted so as to give maximum indicated current; when the internal impedance of the generator is capacitive (*b*), an external variable inductor is employed.

INTERRUPTED CONTINUOUS WAVE. Synonym for TYPE A2 WAVE.

INTER-STATION INTERFERENCE. See NOISE SUPPRESSION.

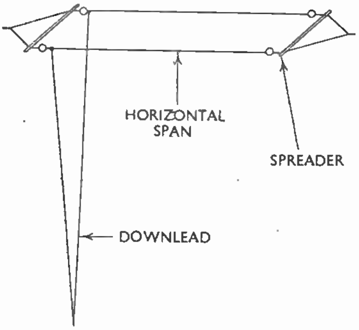


Fig. 19. Elementary form of inverted-L aerial with twin-wire span held on single-spar spreaders.

INTER-STATION NOISE SUPPRESSION. See NOISE SUPPRESSION.

INTER-VALVE COUPLING. Any device used to transfer the output of one valve to the input of another. Possibly the commonest circuits for inter-valve coupling are those which employ resistance-capacitance combinations or those using transformers. See AMPLIFICATION.

INVERSION. Reversal of order of speech-frequencies, used for purposes of secrecy. At the sending end of the system, each frequency is replaced by its difference from 3,000 c/s, the same process at the receiving end restoring intelligibility. See SPEECH INVERSION.

INVERTED AMPLIFICATION FACTOR. Measure of the performance of a valve which may be defined as the ratio between that differential change of voltage on the grid for unit change of anode voltage necessary to keep the anode current constant.

INVERTED AMPLIFIER. Amplifier using the LUNAR-GRID VALVE (q.v.). The term is also applied to the GROUNDED-GRID AMPLIFER (q.v.).

INVERTED-L AERIAL. Aerial in which the main part is a horizontal span, with a down-lead, or lead-in, at one end to sender or receiver (Fig. 19). This type of aerial has distinct directive properties, its maximum efficiency being developed along the line of the horizontal section, in the direction of the down-lead end. Developed early in the history of radio communication, the inverted-L is still in considerable use on medium and low frequencies wherever a moderate amount of directivity is desired. It will be appreciated that this directivity is marked only when the horizontal span of the aerial is of adequate length; the small· aerials used for broadcast reception, though often of inverted-L form, show little directivity because their length is so small compared with the wavelength.

The inverted-L aerial is often valuable for shipboard use, where space may be strictly limited. Here, too, little directivity will be apparent. The natural wavelength of the inverted-L is greater for a given length of horizontal span than that of the other principal flat-top type, the T-aerial. See DIRECTIVITY, FLAT-TOP AERIAL, T-AERIAL.

INVERTED-V AERIAL. Aerial, usually consisting of a single wire, with ends anchored at or near ground level and the mid-point raised to a suitable height. One end is connected to earth via the receiver and the other through a fixed resistor to an earth which may consist of crossed half-wave dipoles (Fig. 20). This aerial, sometimes used on the higher frequencies, is strongly

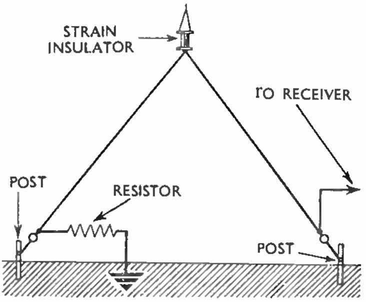


Fig. 20. Simple inverted-V aerial; the end remote from receiver is earthed through a resistor of about 600 ohms.

directive, receiving most efficiently those signals approaching from the end remote from the receiver.

INVERTER CIRCUIT. Apparatus, usually consisting of filters and modulators, for the inversion of music or speech.

ION. Charged particle in a liquid or gas, which is attracted by a negative or positive electrode, according to the charge on the ion. The ion, in moving to the electrode, sets up the equivalent of an electric current in the process. An ion may be a charged molecule, atom, or a radical (i.e. group of atoms which normally forms a section of a molecule).

IONIC BEAM. Beam of ions. See BEAM, CATHODE-RAY TUBE.

IONIC CURRENT. See GAS CURRENT, IONIZATION CURRENT.

IONIC FOCUSING. Synonym for GAS FOCUSING.

IONIC MODULATION. Method of amplitude-modulating a very-high-frequency wave by passing it through a gas which is ionized to a degree directly proportional to the instantaneous amplitude of the modulating wave. Modulation occurs because the carrier wave is absorbed to an extent which depends upon the degree of ionization. See AMPLITUDE MODULATION, IONIZATION.

IONIC VALVE. Synonym for VALVE (q.v.), better defined as "electronic valve." If a gas-filled valve or glow-tube is meant (since, in these devices, ions as well as electrons carry the space current) then it is better to call them by their more descriptive and accurate names. See GAS-FILLED VALVE, GLOW-TUBE, VALVE.

IONIZATION. Breaking up of molecules and atoms in a gas to form ions and electrons. In ionization by collision, which is the effect occurring in GAS-FILLED VALVES (q.v.) and GLOW-TUBES (q.v.), the process is set up by establishing a potential gradient through the gas. The process of ionization may be induced either by applying a sufficient potential between two conductive, but cold electrodes in a bulb containing the gas; or by arranging that one of the electrodes shall emit electrons and be negatively charged with respect to the other. The former principle is applied in the glow-tube, the latter in the gas-filled valve.

As the gas is at a very low pressure, there are relatively few molecules and atoms; in a glow-tube, the effect of gradually increasing the potential difference between the electrodes is that, when this reaches a certain value, one electron breaks away from a particle, leaving it positively charged, and is accelerated towards the anode. It collides with another neutral particle and knocks away another electron.

A chain of collisions is thus set up and electrons are rapidly liberated, leaving positive ions each time a collision occurs. In time, a state of equilibrium is reached, in which there is a number of free ions and free electrons, and as rapidly as some recombine, others are released. The free electrons and the free ions move in opposite directions, the former towards the anode, the latter towards the cathode. Thus the gas is made conductive.

In a gas-filled valve, the process is similar, but a smaller potential gradient is sufficient to start the process, because there is already a copious supply of free electrons from the cathode. Thus, in a gas-filled valve, ionization starts with a potential difference of, perhaps, 15 V, whereas in a glow-tube the so-called striking voltage is never lower than about 60–70 V.

Directly ionization starts in a GAS-FILLED VALVE positive ions begin to fall on to the cathode. The effect is to neutralize the space charge (see SPACE CHARGE). Thus more electrons become available to knock away others from the neutral atoms and molecules and so release more positive ions which further cancel the space charge. This neutralization of the space charge is the important feature of a gas-filled valve; it limits the current that may be safely passed through the valve. If the current is excessive, the bombardment of the cathode by positive ions is severe enough to destroy it (see GAS-FILLED VALVE, MERCURY-VAPOUR (HOT-CATHODE) RECTIFIER).

There are various terms relevant to the process of ionization; in connexion with voltage, the term ionization potential signifies the voltage necessary to start the chain process; the term striking voltage applies to a glow-tube. Once the striking voltage is exceeded, ionization starts, and may be maintained at a low voltage, which is the ionization potential. The voltage drop is the anode-to-cathode voltage when current is flowing. The current is called the ionization current, and that part of it which is carried by positive ions is called the gas current. See GAS CURRENT, IONIZATION CURRENT, IONIZATION POTENTIAL, STRIKING VOLTAGE, VOLTAGE DROP.

IONIZATION CURRENT. Total current flowing through an ionized gas. See GAS CURRENT.

IONIZATION GAUGE. Gas-filled triode used to measure the pressure of residual gas contained in a chamber connected to the valve envelope.

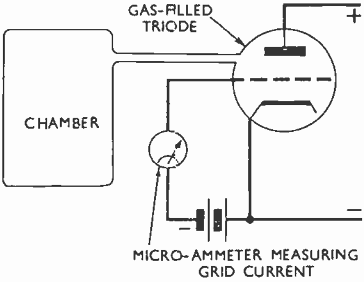


Fig. 21. Circuit connexions showing the principle of the ionization gauge. The envelope of the triode is connected to the chamber containing the residual gas in question.

When the grid of a gas-filled triode is negative with respect to cathode, it attracts positive ions. Thus a current will flow through a micro-ammeter connected between grid and cathode (Fig. 21), as the grid is equivalent to the positive pole of a battery. The pressure of gas within the valve envelope is related to the number of molecules in it, which number is related to the grid current. Thus the gas-filled triode can be used to measure the pressure of a gas. See GAS CURRENT, GAS-FILLED TRIODE, GRID CURRENT.

IONIZATION POTENTIAL. Minimum potential that will cause ionization of a gas. Where the glow-tube is concerned, the term "striking voltage" is often used instead of ionization potential. In a gas-filled valve, the ionization potential is very little different from the voltage drop, but in a glow-tube the potential necessary to start ionization is appreciably greater than that necessary to maintain it. In other words, the ionization potential of a glow-tube is greater than the voltage drop. See GAS-FILLED VALVE, GLOW-TUBE, IONIZATION.

IONIZED GAS DETECTOR. Early type of detector in which the received signal initiates a discharge through an ionized gas.

IONOSPHERE. That region of the atmosphere above the earth's surface which is capable of being ionized. Ionization is the name given to the action which takes place when some of the electrons detach themselves from the atoms of a gas and have free movement. At normal temperatures and pressures, ionization of the atmosphere is negligible, but as the pressure decreases, so the tendency to ionization increases. A gas that is ionized becomes capable of partial electrical conduction. The ionizing agent in the case of the upper atmosphere is the sun, ionization being due in part to direct electron bombardment of the gas atoms, and partly due to ultra-violet, and probably cosmic-ray, radiation.

It is the electrical properties of the

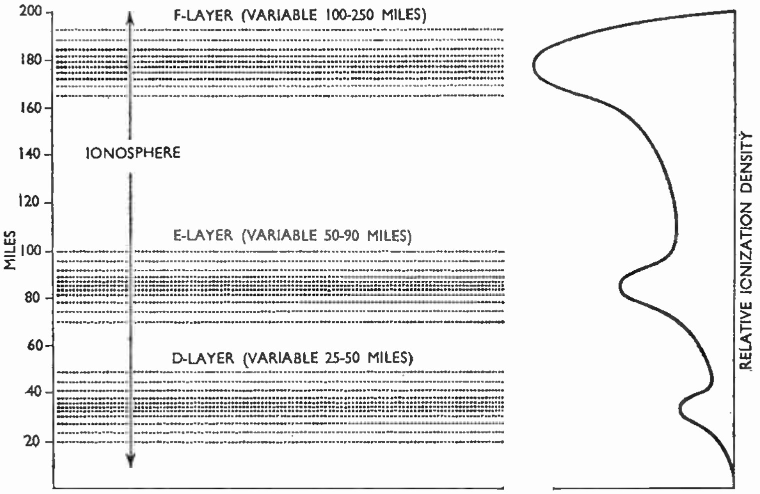


Fig. 22. Diagram showing how the ionosphere is divided into layers; the area contained by the curve (*right*) gives an approximate indication of the ionization.

atmosphere in which radio engineers are directly interested. Electrically, the region from about 10 to 50 miles above the earth's surface is called the D-region, and in this region there is evidence that at least one ionized layer exists at a height varying from 25 to 50 miles. This is known as the D-layer (Fig. 22) and is probably due to cosmic-ray radiation from the sun. Slight evidence exists for a C-layer at a height of some 20 miles, the characteristics of which seem very variable.

In 1902, Kennelly in the U.S.A. and Heaviside in England suggested that a reflecting layer of ionized gas must exist high up in the atmosphere. This has since been proved by pulse measurements, and is thought to be due to direct electron bombardment from the sun. This reflecting layer is known as the E-layer; its height is variable and between 50 and 90 miles. The density of the E-layer varies with the sun's altitude. Thus it is greatest at noon in summer, and at a minimum during the night. The density of the E-layer is known sometimes to increase considerably for a short time, and there may be patches of increased density. The reasons for these sporadic conditions are not definitely known.

Further investigations by Appleton in 1925 disclosed the presence of a still higher layer at a height varying between 100 and 250 miles. This higher layer has been called the F-layer, and appears to be due to ultra-violet radiation from the sun. During the day, when the intensity of ionization is greatest, the F-layer divides into two separate layers spaced about 100 miles apart. The upper sub-layer is called the F2-layer, and the lower the F1-layer.

The actual density of the various ionized layers depends not only upon diurnal and seasonal changes, but also upon the 11-year solar cycle. During the years when sunspots are most numerous the electron density becomes greater. The last two years of maximum sunspot activity were 1937–38 and 1948–49; another maximum will occur in 1959–60.

It appears, therefore, that there are at least three semi-conducting layers, widely separated in space, and each capable of reflecting waves of certain frequencies, within a wide region known as the Ionosphere. See B-LAYER, C-LAYER, D-LAYER, E-LAYER, F-LAYER, IONOSPHERIC REFLECTION, IONOSPHERIC REFRACTION.

IONOSPHERIC-PATH ERROR. That component of the total error of a direction-finding system which arises from lateral deviations of the radio-waves which reach it by reflection from the ionosphere.

IONOSPHERIC RAY. Component part of a radio-wave arriving at a receiving aerial by way of reflection from an ionized layer. A radio-wave emanating from a sending aerial is propagated into space in all directions and has an infinite number of paths; but when energy going in one direction only, within an extremely thin sector of the radiated hemisphere is considered, it is permissible to regard rays of radio energy as having similar characteristics to those of light rays. The rays which are drawn in explanatory diagrams have no separate existence, however, and are merely representative of an infinite number of other possible paths. See IONOSPHERE.

IONOSPHERIC REFLECTION. Reflection of radio-waves by the various ionospheric layers. The waves from a non-directional sending aerial travel outwards in space as well as along the surface of the earth, the large majority of them eventually reaching one or other of the ionospheric layers. When a ray arrives at the effective surface of an ionized layer, reflection, refraction, or both may take place, depending upon the angle of incidence, frequency in use, and the ionic density of the layer (Fig. 23).

The velocity V of an electromagnetic wave is given by the formula $V = \frac{3 \times 10^8}{\sqrt{\mu K}}$, where μ is the permeability of the medium, K the relative permittivity of the medium, and V is given in metres per second.

The permeability is approximately unity for all except ferro-magnetic materials. The relative permittivity K is approximately unity in air, but for ionized gases, such as the E- and F-layers, it is less than unity. The exact value of K depends upon the ionization density and the frequency in use.

Consequently, a ray striking, say, the E-layer, starts to move with greater velocity, and the deeper its penetration of the layer, the greater its velocity. As a result, the higher parts of the wave front travel faster than the lower parts, and cause the wave to bend. The higher part of the wave front is said to possess greater phase velocity than the lower part; the velocity of the whole of the wave front is called the group velocity. The group velocity cannot exceed the

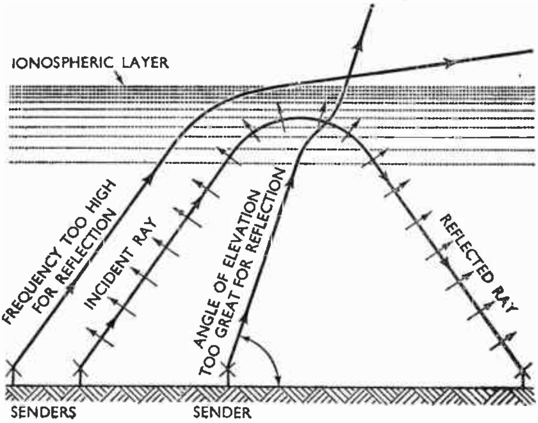


Fig. 23. Simplified diagram illustrating the reflecting properties of the ionosphere. Some rays are not subject to ionospheric reflection because the frequency of the radio-wave is too high, or because the angle of elevation of the ray is too great.

velocity of light. The effect of an ionized layer is thus to cause a gradual bending of the direction, and if the bending is sufficient to direct the ray toward the earth at a distance from the sender, a process akin to reflection of light by a mirror takes place. In general, the higher the frequency the less does the value of *K* depart from unity, and in any particular layer the degree of bending will be less. See E-LAYER, F-LAYER, IONOSPHERE, IONOSPHERIC REFRACTION, SKIP DISTANCE, WAVE VELOCITY.

IONOSPHERIC REFRACTION. Refraction or bending of radio-waves by one or more of the ionized layers. The ratio of the velocity of radio-waves in free ether to the velocity of waves in an ionospheric layer is known as the refractive index of the layer. The degree of refraction that the wave undergoes depends on the refractive index of a layer and the angle of incidence of the wave.

The refractive index of air at normal temperatures and pressures is approximately unity; but the refractive index n of any other medium is given by the formula n (refractive index) $= \sqrt{K}$, where K is the relative permittivity. In the case of the E- or F-layers, K varies according to the intensity of ionization and wave frequency, but is always less than unity. It follows from this that the lower the frequency and the greater the intensity of ionization, the greater will be the degree of refraction.

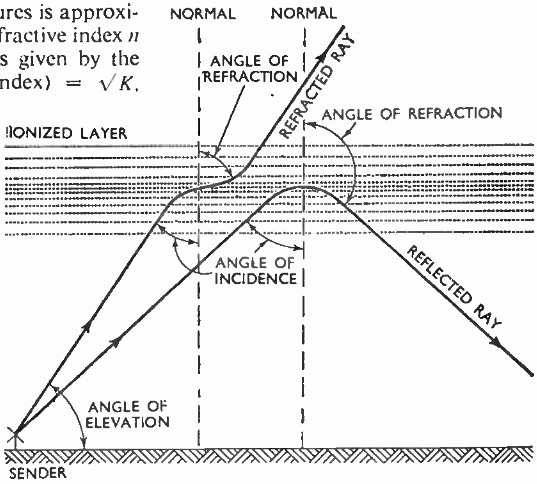


Fig. 24. Diagram illustrating how the degree of refraction of rays entering an ionized layer varies according to the angle of refraction, reflection of the ray occurring only when the angle of refraction is greater than 90 deg.

If the angle of incidence is sufficiently great for the conditions prevailing, then the angle of refraction becomes so large that reflection occurs and the radio-wave is returned to earth (Fig. 24). The angle of refraction is, in fact, constantly changing all the time the wave is in the layer, being at a maximum in the centre of the layer where the ionization density is greatest, and decreasing at the edges of the layer. See ANGLE OF INCIDENCE, E-LAYER, F-LAYER, IONOSPHERIC REFLECTION, REFRACTION.

IONOSPHERIC WAVE. Wave which travels along an IONOSPHERIC RAY (q.v.).

IRON-CORED COIL. See IRON-CORED INDUCTOR, IRON-CORED TRANSFORMER.

IRON-CORED INDUCTOR. Inductor having a core of magnetic material, usually an alloy of iron, in order to reduce its volume for a given inductance. The benefit of a magnetic core is most pronounced at low frequencies where the iron losses are of small magnitude. Nevertheless, even at mains frequencies it is found beneficial to build up the core from insulated laminations of the material so as to reduce the eddy-current losses.

At mains and audio frequencies, silicon alloys of iron, which have a higher permeability and lower losses than ordinary soft iron, are used. At audio and carrier frequencies, nickel-iron alloys are used which, although more expensive, are better than silicon alloys in the respects mentioned. At radio frequencies, the losses become impracticably large, except in the case of cores moulded from finely divided particles of magnetic material (called dust-cores) which have a limited use.

In construction, iron-cored inductors are similar to iron-cored transformers. See FIXED INDUCTOR, IRON-CORED TRANSFORMER, IRON LOSS, LAMINATION.

IRON-CORED TRANSFORMER. Any transformer having an iron core. Such transformers are commonly used at audio frequencies and power frequencies, but by using very thin laminations they are made suitable also for frequencies up to hundreds of kilocycles. See IRON DUST, LAMINATION, TRANSFORMER.

IRON DUST. Finely powdered soft iron often used in inductor cores to increase efficiency by increasing inductance and concentrating the magnetic field in a narrow area. Such an inductor occupies less space than an air-cored one of similar value and, because of the smaller magnetic field, where screening is required, the screen may be placed closer to the inductor.

IRON LOSS. In an iron-cored transformer or iron-cored inductor, the loss due to eddy currents and hysteresis in the iron. When an alternating current flows in the windings of an iron-cored transformer or inductor, it sets up varying magnetic flux in the iron.

This flux induces eddy currents in the iron and, in magnetizing the iron first in one direction and then the other, produces what is known as hysteresis (see HYSTERESIS FACTOR). Energy is inevitably absorbed by these effects, which results in a loss of efficiency in the transformer or inductor. See EDDY CURRENT, IRON-CORED TRANSFORMER.

ISOCHRONISM. See SYNCHRONISM AND ISOCHRONISM.

ISOLATOR. Synonym for BUFFER STAGE. The term is also used to denote a mains switch controlling a number of circuits.

ISOTOPES. Substances whose chemical properties are similar but whose atomic weights are different. Their atomic nuclei are considered to differ in mass but to be the same in charge, and to be surrounded by the same number of electrons.

ITERATIVE IMPEDANCE. Of a quadripole, the value of an impedance measured at one pair of terminals, when the other pair of terminals is terminated with an impedance of equal value. Fig. 25 shows a quadripole and illustrates the meaning of the term; when terminals 3 and 4 are connected to a 500-ohm resistor, terminals 1 and 2 show an impedance of 500 ohms; when 1 and 2 are terminated by 1,000 ohms, terminals 3 and 4 have an impedance of 1,000 ohms. The two iterative impedances are, in general, unequal; but in the special case when they are equal, their common value is called the characteristic impedance of the network. Symmetrical networks thus have a characteristic impedance, and asymmetrical ones an iterative impedance. See CHARACTERISTIC IMPEDANCE, IMAGE IMPEDANCES.

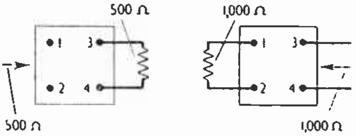


Fig. 25. Iterative impedance of a quadripole; the diagrams illustrate the example quoted in the text.

J

J. Abbreviation for JOULE(S).

JACK. Device used to obtain quick connexion to a circuit. Connexion is obtained by inserting a plug in the jack, the tip, ring and sleeve of the plug respectively making contact with corresponding springs (Fig. 1) in the jack. Jacks are extensively used in telephone switchboards.

JAMMING. Interference due to unwanted signals, sufficiently strong to render the desired signal wholly or partly unintelligible. The term is often used for deliberate interference, the use of which was developed to a high pitch in the Second World War. See INTERFERENCE.

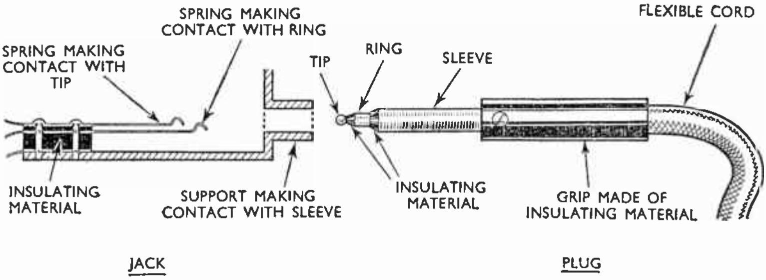


Fig. 1. Section through a jack into which a plug (*right*) is inserted; it is employed to make quick connexion. The drawing is not to scale.

JANSKY NOISE. See ATMOSPHERICS.

JAR. Obsolete unit of capacitance once much used in the British Navy. It is equal to 0·0011 microfarad.

JIGGER. Auto-transformer at one time used in spark senders as a coupling between an intermediate circuit and the aerial.

JOHNSON NOISE. See THERMAL-AGITATION VOLTAGE.

JOULE. Energy unit defined as the amount released by a current of one ampere flowing for one second through a resistance of one ohm. The abbreviation is J. See WATT.

JOULE'S LAW. Law which states the relation between heating effect and current, resistance and time. It states that the heat generated is directly proportional to the product of the resistance (R) and the time (t) for which the current flows, multiplied by the square of the current (I). In symbols, therefore,

$$\text{heat produced} \propto I^2Rt.$$

K

k. Abbreviation for kilo, a prefix meaning thousand, as, for example, in kW (kilowatt), kV (kilovolt).

KALLIROTRON. Untuned circuit in which two triodes are used to give an effective negative resistance.

kc/s. Abbreviation for KILOCYCLES PER SECOND.

KEEPER. Substance which is placed in the bulb of a hard-vacuum valve and tends to absorb, by chemical action, any gas released in the bulb after manufacture is completed. In the manufacture of a hard-vacuum valve, the process of degassing involves pumping, heating of electrodes while pumping, and sometimes the use of a getter. In spite of these processes, it is possible for occluded gas to be released some time after manufacture and the valve may, in consequence, go "soft" (see SOFT-VACUUM VALVE). In order to minimize this effect, a keeper may be placed within the bulb which tends to absorb any gas released when the valve is in operation. Certain getters may also act as keepers. See DEGASSING, GETTER.

KENNELLY-HEAVISIDE LAYER. Original name for that ionospheric layer now more commonly known as the E-layer. The E-layer was discovered by the scientists Kennelly and Heaviside, working independently of each other, in the year 1902. Appleton, in 1925, introduced a new terminology for the two layers known to exist at that time, calling them the E- and F-layers. See E-LAYER, IONOSPHERE.

KENOTRON. American name for a VACUUM-VALVE RECTIFIER. See also DIODE.

KERR CELL. Device for the electrical modulation of light. The cell consists, fundamentally, of a transparent container filled with nitro-benzine. Polarized light is passed through the liquid and between two banks of metal plates resembling the plates of a variable capacitor. As the potential across the two banks of plates is varied, so the polarized light beam is more or less rotated, away from its axis of vibration.

In itself, the Kerr cell will not provide a form of light modulation that can be used for television because it is not a *quantity* controller, merely twisting the plane of the light passing through it. Owing to capacitance effects, the Kerr cell cannot be used for high-definition television; it can, however, be used in low-definition television as follows: Ordinary light is passed through a polarizer of Iceland spar. It emerges plane-polarized and is then passed through the Kerr cell as illustrated in Fig. 1.

The output of the television receiver is connected to the plates of the cell, already biased to its most sensitive condition. The light emerges from the Kerr cell, and is passed through a second polarizer which will pass light only in a plane at right-angles to the light passed by the first filter. Thus, when no potential is applied to the Kerr cell and no rotation of the plane of polarization occurs, no light passes through the second polarizer.

As the plane of the light is rotated by the Kerr cell, operated by the television signal, more and more light is allowed to pass by the second polarizer, maximum light passing when the plane rotation is 90 deg. In practice, the Kerr cell is biased to a point where light is just beginning to pass, and any added potential causes more light to pass. Synchronizing signals, which reduce the potential across the cell plates, reduce the rotation of the plane of

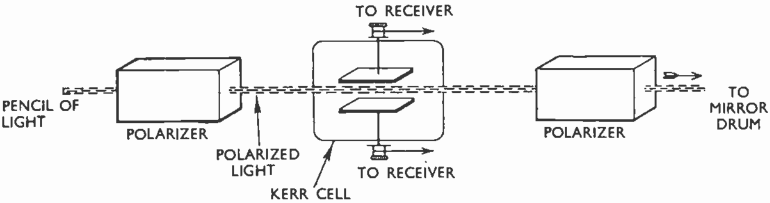


Fig. 1. The Kerr cell rotates the plane of polarized light according to the potential across the plates of the cell. The second polarizer passes only light which is in a plane at right-angles to that passing the first polarizer.

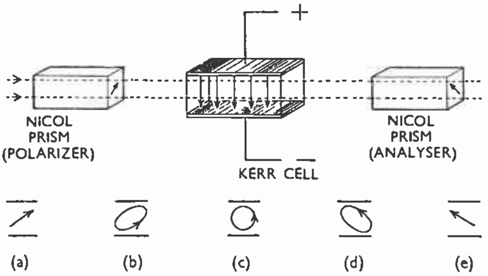


Fig. 2. If monochromatic light, which is plane-polarized at 45 deg. to the electrostatic field in a Kerr cell, is passed through the cell, the plane of polarization can be rotated by increasing the potential. An indication of this is given in the small diagrams from (*a*) to (*e*).

the light and cut it off altogether.

Many attempts have been made to reduce the self-capacitance of the Kerr cell sufficiently for it to be used with high-definition television. Results, however, have not been promising. Divergent plates assist in reducing the capacitance, but it is still a serious drawback. A further drawback, not directly connected with the Kerr cell, is the fact that light-modulation of this type is of use only with mechanical methods of scanning, and these, in themselves, are clumsy and unsatisfactory for high definition.

KERR EFFECT. Phenomenon, discovered by Professor Kerr, that, when certain media are subjected to electrostatic stress between a pair of plates, the media become birefringent. Instead of light vibrations passing in their full proportions through a medium of this type, regardless of the plane of the vibrations, only vibrations in one particular plane are passed fully.

Other vibrations are retarded. The resultant vibration is one that is a component of the various vibrations passed, and is in a direction dependent on the optical axis of the cell formed by the medium between the metal plates, and on the potential between the plates.

Tourmaline is a substance which is naturally birefringent, but Kerr discovered that the effect can be produced and controlled by forming cells of such liquids as carbon disulphide, chloroform, nitrobenzene and metanitrotoluene, with two metal plates as electrodes between which the electrostatic potential could be applied.

Now, if plane-polarized light is passed between the plates (Fig. 2) when a potential difference between them is applied, the liquid will become birefringent and will split the plane-polarized light into two rays moving with unequal velocities in the liquid. On emergence, the two rays, which are unequally retarded, will join to form elliptically polarized light from which a component can be selected by a Nicol prism. This component can be changed by varying the potential across the Kerr cell, and thus varying the retardation of the two light rays passing through the cell.

Rotation of the plane-polarized monochromatic light can be seen from the diagrams in

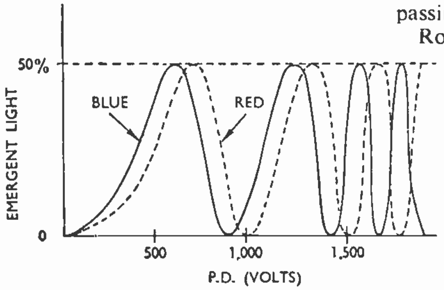


Fig. 3. Graph which gives an indication of the difference over the spectrum of emergent light at increasing values of the potential across the plates of a Kerr cell.

Fig. 2, where light, polarized in a plane at 45 deg. to the direction of the electrostatic field in the Kerr cell, is passed through the cell and rotated through 90 deg. This rotation can be increased or decreased by varying the potential across the plates of the Kerr cell.

If the polarizer (first Nicol prism) and the analyser (second Nicol prism) are so crossed that their planes of polarity are not at 90 deg. to one another, the maximum amount of light that can be passed is decreased and it is impossible to cut off the light completely, no matter how the voltage of the Kerr cell is varied. If the electrostatic field in the cell is not at 45 deg. to the planes of polarization passed by either of the prisms, complete cut-off of light can be achieved, but the maximum amount of light which can be transmitted is reduced. The best conditions are those illustrated, where the planes of polarization accepted by the prisms are 90 deg. to each other, and each is 45 deg. to the field of the Kerr cell.

In this condition, not only can the best effects be obtained with monochromatic light, but variations with wavelength are at minimum, as shown by Fig. 3, provided the potential across the Kerr cell is kept low. If the potential is increased, the amount of light emerging varies considerably with position in the spectrum band. To overcome this disadvantage, and to allow the steepness of the high-voltage characteristics to be used to gain sensitivity, it has been proposed to use a compensating retardation plate of mica so that a higher bias potential can be applied to the Kerr cell.

The time-lag of the Kerr cell is very short, being of the order of less than 0·00002 second. This has enabled Kerr cells to be used for television where modulation of light is necessary. See KERR CELL.

KEY. One of several classes of switch used in communication and test equipment. A telegraph or morse key is a single-pole, two-way switch designed for rapid manual operation for generating telegraph signals of the morse type (see MORSE CODE).

A telephone key is a switch having laminar cantilever contacts which are flexed rather than pivoted (Fig. 4) like contact springs of a relay. For applications where the inter-contact capacitance of the standard key is excessive, a "low-capacitance" key is available having stiff-wire contact members instead of leaf springs.

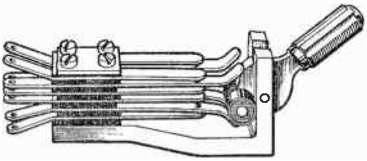


Fig. 4. Key switch with leaf-spring contacts, for use where low capacitance is not essential. A modified type can be used in some R.F. circuits.

KEY CLICK. Transient sidebands produced by the sudden stopping and starting of a carrier wave due to keying. These may be sufficiently remote in frequency from the carrier wave to cause interference, heard as clicks, on other channels. The time constants of the keying system should be arranged so that the growth and decay of the carrier wave is not more rapid than is necessary for well-formed characters. See KEYING.

KEYED CONTINUOUS WAVE. See TYPE A1 WAVE.

KEYED MODULATED WAVE. See TYPE A2 WAVE.

KEYING. Operation of interrupting electrical circuits in a telegraph or radio-telegraph system. The operation may be manual or, for high-speed keying, automatic.

KEYSTONE EFFECT. Distortion of a television frame, as shown in Fig. 5, caused by the line scanning being modulated by the frame scanning. It is produced also when the screen is not normal to the axis of the beam, as

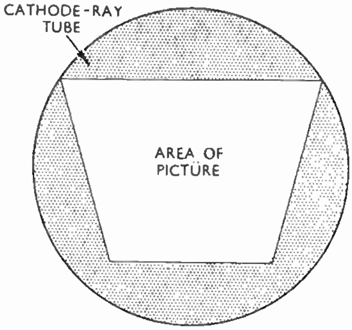


Fig. 5. Distortion of a television frame, known as keystone effect, which may be caused by modulation of the line scanning by the frame scanning.

in the electron camera. Here deliberate keystone distortion is introduced in the scanning system in order to counteract the distortion due to the screen not being at right-angles to the beam. See ELECTRON CAMERA.

KILOCYCLES PER SECOND. See CYCLES PER SECOND.

KILOMETRIC WAVE. Radio-wave of 1,000 to 10,000 metres wavelength; that is, within a frequency range of 30–300 kc/s. See LOW-FREQUENCY WAVE.

KILOVOLT-AMPERE. Unit of apparent or nominal power (abbreviated kVA), equal to 1,000 VA. See VOLT-AMPERE.

KILOWATT. Unit of power (abbreviated kW), equal to 1,000 watts. See WATT.

KILOWATT-HOUR. Unit (abbreviated kWh) which expresses the rate of power delivery or consumption, taking into account both the magnitude of the power-flow and its duration. A power of 5 kW in use for 2 hours represents a power consumption of 10 kWh.

KINKLESS TETRODE. Term used to describe a tetrode in which the effects of secondary emission have been eliminated. The term recalls the shape of the anode-volts/anode-current characteristic of early tetrodes in which a negative slope resistance appears. It is this negative resistance which makes possible the construction of dynatron oscillators. See SECONDARY EMISSION, TETRODE.

KIRKIFIER. Circuit devised by H. L. Kirke before low-impedance diode rectifiers were available. It uses a triode with a positive voltage applied to the grid. Such an arrangement exhibits a marked non-linear characteristic, and has a performance similar to that of the low-impedance diode rectifier.

KLYSTRON. Valve in which the electron stream is made to form into bunches by the action of a RHUMBATRON (q.v.), or cavity resonator. The valve may be used as either an amplifier or generator of centimetric waves. The action of the klystron is shown in Fig. 6, in which it is seen that the valve comprises an oscillator whose feedback arrangement is formed by the interconnexion, by a tube, of two cavities which are known respectively as the buncher and the catcher.

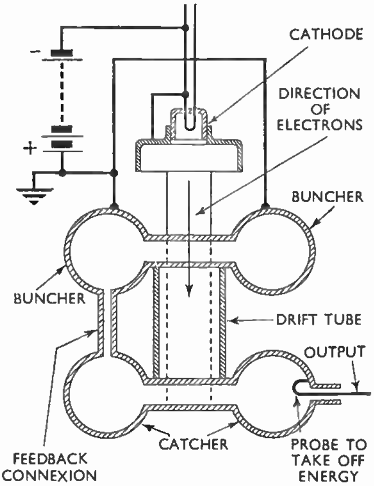


Fig. 6. Diagram showing in section a klystron as used for the generation of centimetric waves; connexions to external circuits are also indicated.

The cathode is biased negatively with respect to the earthed anode (catcher). Thus electrons are accelerated towards the opening of the buncher, which acts as a grid in controlling the electron stream.

Imagine that the field in the gap in front of the buncher is rising and falling in intensity; rising from zero positively, it accelerates electrons coming towards it from the cathode and slows down electrons that have passed beyond it into the drift tube. Rising from zero negatively, the field slows down the electrons approaching on the cathode side of it and repels, i.e., accelerates, the electrons which have passed the buncher and are in the drift tube. The total effect is that of a periodic concentration (or bunching) of electrons in the stream in the drift tube.

The bunched beam passing the mouth of the catcher excites the rhumbatron into oscillation; thus, by means of the interconnexion of the two cavities, there is a feedback of energy from catcher to buncher and the action, like that of any oscillator, is regenerative. The natural frequency of oscillation is that of the rhumbatron, which resembles a tuned-anode circuit and tuned-grid circuit in a triode oscillator, the former being the catcher, the latter the buncher.

Energy is taken from the catcher by a probe. (The same method of drawing-off energy is used in the multi-cavity magnetron.) Since the velocity of the electrons in the drift tube must be changed to cause bunching, the valve is often called a velocity-modulation valve. See MAGNETRON, OSCILLATOR.

kVA. Abbreviation for KILOVOLT-AMPERE.

kW. Abbreviation for KILOWATT.

kWh. Abbreviation for KILOWATT-HOUR.

L

LABORATORY OSCILLATOR. Synonym for FREQUENCY-STABILIZED OSCILLATOR.

LADDER NETWORK. Term describing a cascade connexion of similar networks with series and shunt arms. A multi-section filter may be described as a ladder network. See FILTER SECTION.

LAG. Extent to which an alternating current falls behind the voltage cycle in an inductive circuit. See LAGGING CURRENT.

LAGGING CURRENT. Alternating current which reaches its successive maximum values after the voltage reaches its maximum values, a condition characteristic of circuits which are predominantly inductive. The extent of the lag decides the power factor of the circuit; it is calculated in terms of an equivalent angle in the 360-deg. cycle. See POWER FACTOR.

LAGGING LOAD. Alternating-current circuit in which the current is caused to lag behind the voltage by the mainly inductive effect of the load. The load is consequently sometimes called an inductive load.

LAMINATION. Of an iron-cored transformer or inductor, a ferromagnetic sheet shaped so that, with other similar sheets, a structure may be built up as a partly or wholly closed iron circuit suitable to form the core of the transformer or inductor. An iron core is made up of laminations so as to prevent serious loss due to eddy currents. The thinner the metal, the less is the eddy-current loss. Laminated iron-cored transformers can be used up to frequencies of hundreds of kilocycles provided the laminations are very thin. One of many different types of iron may be used, depending upon the requirements of flux density, iron loss, incremental permeability and the frequency of a cycle of magnetization. See CORE, INDUCTOR, TRANSFORMER.

LATERAL DEVIATION. Deviation or divergence of the ground wave when the great-circle route between sender and receiver is roughly parallel to a coast line. The accuracy of any radio direction-finding system is based on the assumption that the radio-waves follow a great-circle route, which is the shortest distance between any two points on the earth's surface. If the great-circle bearing is parallel to a coast line, then the ground wave suffers greater attenuation whilst passing over land than it does over sea. This results in a shifting of the wave front, and the wave arriving at the receiver tends to be bent in such a way as to cause the sender bearing to be displaced seawards from the true bearing of the sender.

Bearings that are within about 15 deg. of a coast line are likely to be inaccurate, particularly if the distance from the sender is great. A similar deviation is often found in mountainous areas, since the attenuation of a ground wave travelling up a valley is less than that of a wave travelling crosswise from ridge to ridge. See ABSORPTION, DIFFRACTION, DIRECTION-FINDING.

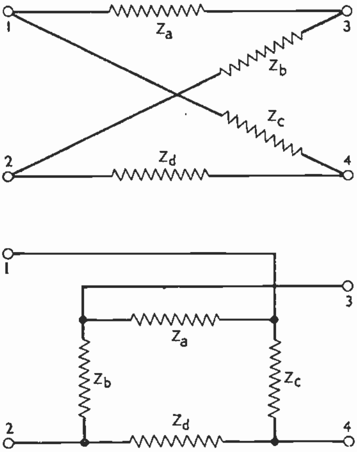


Fig. 1. Two different ways of representing diagrammatically exactly the same lattice network.

LATERAL INVERSION. Mirroring of a television picture. The right-hand side appears on the left, and vice versa, although the picture is the correct way up. Deliberate lateral inversion has to be used when a cathode-ray picture is to be indirectly viewed through a mirror, or when mirror-drum or mirror-screw pictures are viewed on a reflecting screen (see MIRROR DRUM, MIRROR SCREW).

LATERAL RECORDING. Recording system, particularly gramophone, in which the recording stylus moves sideways about a mean position, the depth of the recorded groove remaining constant. See ELECTRICAL RECORDING.

LATOUR ALTERNATOR. High-frequency synchronous generator developed and used in France for radio telegraphy. See SYNCHRONOUS GENERATOR.

LATTICE COIL. Special type of wave-wound coil. See WAVE-WINDING.

LATTICE NETWORK. Network composed of four impedances connected to form a closed circuit. Two non-adjacent junction points are connected to the input terminals and the other two to the output terminals. Fig. 1 illustrates lattice networks and shows two ways of drawing the same network. See BRIDGED T-NETWORK, C-NETWORK, H-NETWORK, L-NETWORK, O-NETWORK, PI-NETWORK, T-NETWORK.

LATTICE-WOUND INDUCTOR. Inductor having a special type of low-capacitance wave-wound coil in which there is a regular pattern of diamond-shaped air-spaces. See WAVE-WINDING.

LEAD. (1) Time or angular interval by which one phase of one alternating quantity preceeds that of a second alternating quantity; (2) general term for connexion by means of a wire.

LEAD-IN. Conductor joining a radio receiver or sender to an aerial.

LEADING CURRENT. Alternating current which reaches its successive maximum values before the voltage reaches its maximum values, a condition characteristic of circuits which are predominantly capacitive. The extent of the lead determines the power factor of the circuit; it is calculated in terms of an equivalent angle in the 360-deg. cycle. See POWER FACTOR.

LEADING-IN INSULATOR. Synonym for LEAD-IN INSULATOR.

LEADING-IN WIRE. Synonym for LEAD-IN.

LEADING LOAD. Alternating-current circuit in which the current reaches its successive maximum values before the voltage reaches its maximum values. See LAGGING LOAD, LEADING CURRENT.

LEAD-IN INSULATOR. Insulating bush mounted in a wall or bulkhead through which passes the conductor joining a radio receiver or sender to an aerial.

LEAK. Circuit of relatively high resistance. A resistor of the order of a megohm connected across a capacitor so that this cannot maintain a charge for very long is termed a leak. A resistor of high resistance value in the grid to the cathode circuit of a valve is known as a grid-leak. (A "bleeder" is not precisely the same thing as a leak but is similar.)

The term "leak" may also be used to describe the effect of bad surface insulation. See BLEEDER RESISTOR, GRID-LEAK, LEAKAGE CURRENT.

LEAKAGE CURRENT. Current, usually small, flowing between circuit points or from a circuit point to earth, either through, or more probably across, the surface of a poor or faulty insulator. See LEAK.

In a valve, a leakage current may flow over the surface of the envelope or from the valve pins to earth. Because of this, an electrode may be, in effect, connected to a point of low potential through a resistor of high value; for example, the grid may be connected to the cathode through a resistance of several million ohms. The electrode collecting electrons or ions becomes charged, and this charge can leak away over the surface of the bulb (from a grid top-cap, for instance) or along the surface of the valve holder. See GRID-LEAK, WATER-COOLED VALVE.

LEAKAGE INDUCTANCE. Of a transformer, the inductance which may be considered to exist in the primary and secondary windings of a transformer due to failure to achieve complete coupling between the windings. If all the flux produced by the primary coil of a transformer cuts all the turns of the secondary coil, the leakage inductance will be zero. If there is not complete coupling, the effects produced are the same as would be produced if an inductor were connected in series with the secondary terminals of an equivalent transformer with perfect coupling, and the load. The value of such an inductor is the value of a leakage inductance. In other words, an imperfectly coupled transformer is the equivalent of a perfectly coupled transformer which has a series inductor connected between it and an output terminal.

The effect of leakage inductance is to produce a falling-off of the secondary voltage as the frequency of the primary current is increased. It is possible to treat leakage inductance as the series arm of a low-pass filter. In such a case, the falling-off of the frequency-response characteristic takes place more rapidly, but at a higher cut-off frequency. This cut-off frequency depends upon the value of the leakage inductance and the terminating resistance.

The value of the leakage inductance may be found by adjusting a capacitor connected across the secondary of the transformer until maximum voltage is developed across the capacitor. Then $\frac{1}{2\pi fC} = 2\pi f L_L$, where C is the value of the capacitor to give voltage resonance, f is frequency, and L_L is the leakage inductance. Thus

$$L_L = \frac{1}{4\pi^2 f^2 C}.$$

See COUPLING COEFFICIENT, FILTER, FILTER SECTION, RESONANCE, TRANSFORMER.

LEAKANCE. Reciprocal of the equivalent resistance of an insulator; the term is derived from "leakage conductance," and denotes simply the conductance equivalent to the very high resistance of an insulator or insulating material. See CONDUCTANCE.

LEAKY-GRID DETECTION. See GRID DETECTION.

LECHER WIRE. Length of two-wire transmission line which is used as a tuned-circuit element, or as a resonant line for the purpose of obtaining wavelength measurements. Such lines are, in general, between ¼ and 4 wavelengths long, and usually have a shorting bar which can be moved to any part of the line.

When used for wavelength measurement, the input end may be coupled inductively or capacitively to the source of radio-frequency energy. Fig. 2 shows a pair of Lecher wires capacitively coupled to the output circuit of a radio-frequency oscillator, and the shorting bar is adjusted at a point which makes the line an odd multiple of ¼ wavelength long; the diagram shows this length as ¾ wavelength. There is reflection of current at the shorting bar and high voltage at the input end; the successive reflections build up a standing wave such that maximum current flows in the shorting bar.

An ammeter inserted in series with the bar indicates a high current but as this current is out of phase with the voltage, no power is supplied by the oscillator. If the bar is now slowly moved along the line towards the oscillator, the current reading on the ammeter will decrease until ¼ wavelength has been covered, when the meter will read zero. By moving the bar another ¼ wavelength in the same direction, a second current maximum is reached, and the difference between the two current maxima is seen to be ½ wavelength. This is a simple, practical method of measuring the wavelength of an oscillator or sender, but the method is obviously practical only at fairly short wavelengths; a ¾-wavelength Lecher line at medium frequencies would be impossibly long and impracticable.

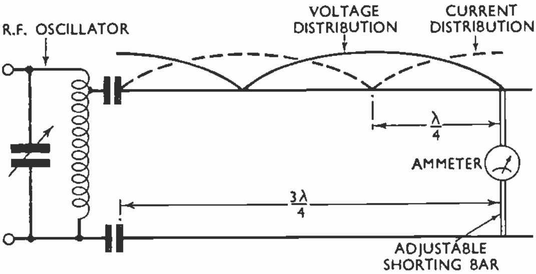


Fig. 2. Standing waves set up on capacitively coupled Lecher wires. The ammeter in the shorting bar reads maximum current at the points of maximum-current distribution, these points being located at half-wave intervals along the line.

An important application of Lecher lines is as a component in oscillator circuits at very high frequencies. Since standing waves may be set up on a quarter-wave, short-circuited feeder, Lecher lines act as parallel resonant circuits and may be substituted for the ordinary coil and capacitor circuits normally employed in oscillators. Lecher wires used in this manner give the advantages of high circuit-magnification, low resistance-losses, and efficient oscillation at frequencies higher than those readily obtainable with coils and capacitors.

The resistance losses of a well designed feeder are almost negligible, and the circuit amplification is the ratio of its inductive reactance to its resistance. If the resistance is low for a given value of reactance, the circuit amplification is correspondingly high. In a single-valve oscillator, the concentric line is commonly used, as it has the advantage that the inner conductor is screened by the outer conductor, which reduces unwanted radiation. Push-pull circuits make use of the balanced twin-wire type of feeder.

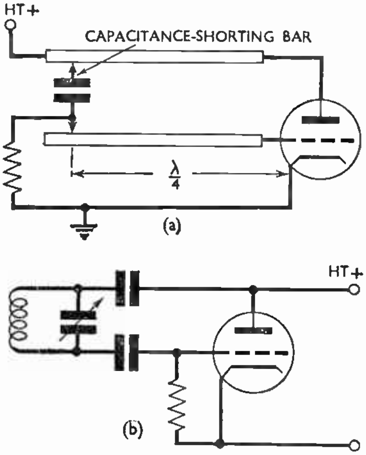


Fig. 3. Simple Lecher-line oscillator suitable for use at very high frequencies (*a*), and its equivalent circuit (*b*). There would, of course, be an anode load (resistor or inductor) between the terminal marked H.T.+ and the positive supply terminal in each case.

Fig. 3 shows a simple form of Lecher-line oscillator and its equivalent conventional circuit of coil and capacitor; this form of valve oscillator readily oscillates at the highest frequency of which the tube is capable. See OSCILLATOR, OSCILLATING CURRENT, Q-FACTOR, STANDING WAVE.

LECLANCHÉ CELL. Form of primary voltaic cell in which the positive electrode is made of carbon and the negative electrode of zinc. The former is usually in the form of a bar, the latter a rod. The electrolyte is a solution of sal ammoniac.

Without means to prevent it, hydrogen forms round the positive electrode and polarizes the cell (see POLARIZATION). A de-polarizer is used, therefore, and consists of a mixture of black manganese dioxide and granulated carbon held around the positive electrode in a porous pot (Fig. 4). The electrolyte soaks through this pot.

When current flows, hydrogen is liberated and combines with some of the oxygen of the de-polarizer. If, however, the current exceeds a given amount, more hydrogen is released than can be absorbed. Thus the current that can be drawn from the cell is limited by polarization; in other words, the internal resistance of the cell is dependent, among other things, upon the effects of polarization. The internal resistance of a Leclanché cell holding about one pint of electrolyte is two or three ohms.

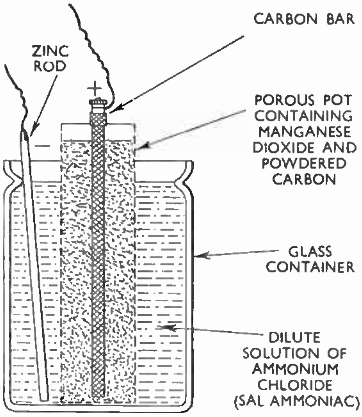


Fig. 4. Section through a wet-type Leclanché cell. The manganese dioxide acts as the de-polarizer, and it is mixed with powdered carbon in order to render it conductive of ions.

A dry cell is basically a Leclanché cell, but the electrolyte takes the form of a paste rather than a liquid. See DRY CELL.

LENS DISC. Form of television scanner in which lenses are used instead of holes in the rotating disc. The lenses concentrate the light and enable a brighter picture to be obtained.

LENZ'S LAW. Law which relates the factors involved in the phenomenon of self-induction (see INDUCTANCE). It states that the voltages induced by a change in the linkages between a conductor and a magnetic field are in a direction which tends to oppose the change of linkage. The law applies in all cases of electromagnetic induction, including that of the transformer.

LEPEL DISCHARGER. Form of QUENCHED SPARK-GAP (q.v.).

LEVEL. See ACTUAL LEVEL, RELATIVE LEVEL, TEST LEVEL.

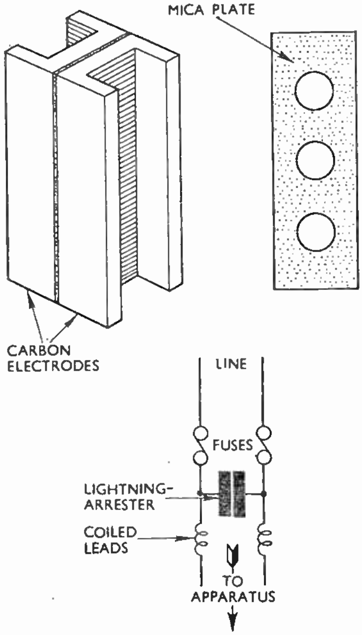


Fig. 5. Form of lightning arrester in which a mica plate, perforated as shown to provide spark-gaps, is clamped between two carbon electrodes.

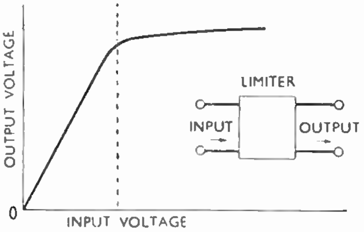


Fig. 6. Characteristic of a practical limiter. An ideal limiter would restrict the output voltage exactly to a fixed maximum when the input voltage increased beyond a certain value.

LEVEL-MEASURING SET. Set of instruments used to measure voltage or power levels at selected points in an electrical transmission system. Basically, it consists of an audio-oscillator, a variable attenuator and a calibrated meter, such as a valve voltmeter. The instruments are normally calibrated in decibels, zero level being taken as 1 milliwatt, or 0·775 volt developed across 600 ohms.

LEYDEN JAR. Earliest form of capacitor, devised in the University of Leyden. It consisted of a glass jar as dielectric, with the inside and outside surfaces of the walls and base coated with metal foil as electrodes. See CAPACITOR.

LIGHT CURRENT. Current provided by electron emission from the cathode of a photocell.

LIGHT FLUX. A measure of the quantity of light energy passing through an area. The light flux passing through a given area depends on the intensity of the source and the distance of the area from it. The unit of light flux is the lumen and is defined as the energy passing through unit area at unit distance from a source with an intensity of 1 standard candle. From this definition it may be seen that 1 standard candle gives rise to 4π lumens. See LUMEN.

LIGHTNING. See ATMOSPHERICS.

LIGHTNING ARRESTER. Device for protecting equipment connected to an outdoor aerial or overhead line from surges due to lightning. In one form, shown in Fig. 5, a multiple spark-gap to earth is provided by perforated mica sandwiched between carbon electrodes. For power-line protection, use is made of special minerals, such as Metrosil, the resistance of which decreases very steeply when the working voltage is exceeded.

LIGHT RAY. Path traversed by electromagnetic wave forms which produce visual sensations on the eye.

LIGHT RELAY. Synonym for PHOTO-CELL.

LIGHT RESISTANCE. Resistance of a photo-conductive material when under the influence of light. See PHOTO-CONDUCTIVITY.

LIMITER. Any device with input and output terminals which maintains the amplitude of a wave at the output terminals substantially constant when the amplitude of the wave at the input terminals exceeds a certain value. The graph of a typical limiter is shown in Fig. 6. It may be noted that there is a proportionality between input and output voltages when the input voltage is less than a certain value; but that when a certain value is exceeded, the output voltage remains almost constant.

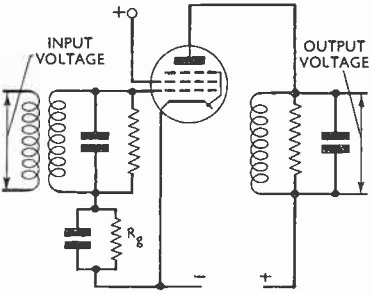


Fig. 7. Circuit of a limiter; grid current flows in R_g to provide negative grid bias whenever the input voltage exceeds a certain value. The ideal characteristic is shown in Fig. 8.

The device is extensively used in frequency and phase modulators to ensure that the amplitude of the modulated wave shall not vary with modulation. The limiter is also used in television reception. The circuit of a limiter is given in Fig. 7. The action is due to the fact that increasing the input voltage beyond certain limits causes grid current to flow in R_g and biases the grid negatively. The amplification of the valve decreases as its grid is made more negative, as illustrated in Fig. 8. See FREQUENCY MODULATOR, NOISE LIMITER, PHASE MODULATION, TELEVISION.

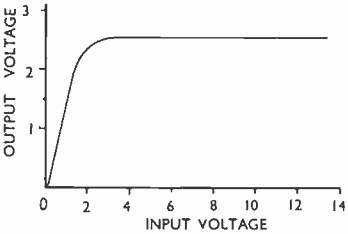


Fig. 8. Form of the response of the limiter circuit illustrated in Fig. 7.

In broadcasting technique, a limiter taking the form of an amplifier is interposed between a programme source and the sender or recording system to prevent overloading of the sender or recording system. It consists of a main amplifier and a side chain, the gain of the former being reduced at excessive programme peak volume by the action of the latter.

Suppose the normal modulation depth of a sender to be 40 per cent and the peak modulation 100 per cent, then the maximum programme volume applied to the sender input must not exceed the normal volume by more than 8 db. ($20 \log_{10} \frac{100}{40} = 8$). The action of the limiter is illustrated in Fig. 9. Programme signals are applied to the input of the main amplifier V_1, one output of which is connected to the sender and the other to the side chain. The valve V_2 is normally

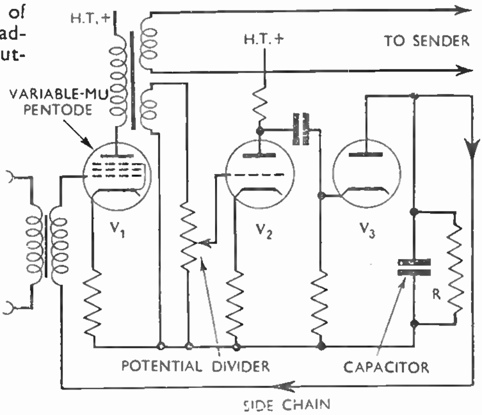


Fig. 9. Theoretical circuit of a typical limiter used in broadcast technique. When the input-signal exceeds a predetermined value, the cut-off bias of V_2 is partly offset, and V_2 passes current. The output of V_2 is rectified by V_3, and the output of V_3 applied to V_1 as negative bias; the gain of V_1 is thus reduced. When the peak signal has passed, the capacitor discharges through R, and V_1 is restored to normal gain. It may be mentioned that, in practice, V_1 is a push-pull stage.

biased beyond cut-off and passes no signal. If the input signal reaches a peak value exceeding 8 db. above normal, the excess signal voltage partly offsets the bias on V_2 which now operates.

The output of V_2 is rectified by V_3, this rectified signal being applied to V_1 as bias, reducing the gain of V_1 by an amount proportional to the excess signal. Thus, if the signal is 2 db. above maximum permissible peak volume, the gain of V_1 will be reduced by 2 db. The example quoted is for 8 db. limitation; other values may be obtained by adjustment of the potential divider.

The source of the biasing potential is the capacitor. To restore the side chain to normal after the excessive peak has passed, a resistor *R* discharges the capacitor. The value of *R* is critical; if too low, the capacitor discharges too rapidly and the limiter behaves as a compressor; if too high, soft passages following an excessive peak may be unduly attenuated, producing a "fading" effect on the programme. See COMPRESSOR.

LINE. Abbreviation of TRANSMISSION LINE.

LINE AMPLIFIER. Amplifier associated with the input to a line running from a control room to a sender, or to a trunk exchange for simultaneous broadcasting. The distinction is made to differentiate a line amplifier from a microphone or A-amplifier.

LINE AMPLITUDE. In a television receiver, the output of the line-scanning generator or the length of the horizontal line produced by the scanning generator on the screen.

LINEAR AMPLIFICATION. Process of amplification in which the final product is a perfect, though enlarged, copy of the original. More precisely, amplification in which the amplitude of the output current or voltage at any instant is greater than the input by a fixed ratio.

Thus, if the output voltage is 20 times the input at a particular instant, so will it be 20 times the input at any other instant, no matter what the actual amplitude or frequency of the input voltage may be; if the input is 1 volt, the output will be 20 volts; if the input is 2 volts the output will be 40 volts; and so on, up to the limit of the apparatus. If one plots a graph of input against output the result will obviously be a straight line; hence the name *linear* amplification.

LINEAR AMPLIFIER. Amplifier in which the output wave of voltage or current is a perfect copy of the input wave. This implies that the output is directly proportional to the input; i.e., there is a linear relationship between output and input. A linear amplifier produces no distortion. See LINEAR AMPLIFICATION.

LINEAR DETECTION. Process of detection in which the audio-frequency output is directly proportional to the modulation. This is not fully achievable in practice because any practical detector exhibits non-linear characteristics to small signals. In other words, the change from the non-conducting to the conducting condition is always gradual.

With a strong signal, however, of the order of 1 volt upwards, the diode detector behaves very nearly as a true linear detector, and a good approximation to linear detection can also be obtained, even with rectifiers which have a fairly large bottom bend, such as an anode-bend detector.

The average depth of modulation of a high-quality broadcast sender is about 40 per cent, and modulation peaks up to 100 per cent are comparatively rare. Thus good reproduction can be obtained even if the rectification is not completely linear. Fig. 10 shows the characteristic of an anode-bend rectifier with a strong applied signal. It will be seen that the limits of variation of carrier amplitude occur over a portion of the characteristic which is tolerably linear.

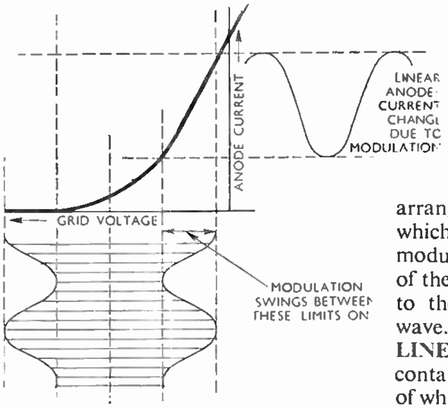


Fig. 10. Graph showing that linear detection is obtained when the depth of modulation is only, say, 40 per cent, even though the characteristic of the detector has a bottom bend.

LINEAR DETECTOR. Detector in which the rectified output is proportional to the modulation depth of the input signal. See LINEAR DETECTION.

LINEAR DISTORTION. See NON-LINEAR DISTORTION.

LINEAR MODULATION. Modulation in which linear amplifiers are used in the modulators, and in which the conductivity or impedance of circuit elements of the modulators is constant. Non-linear modulation is based on the addition of the amplitudes of carrier and modulating waves, and the rectification of the resulting wave; a filter is used to select the modulated wave from the distorted wave.

In linear modulation, the modulating wave influences the carrier-wave amplitude by means of devices which have a linear response. Thus the modulated amplifier, in anode modulation, gives a carrier-wave output proportional to its anode voltage; in commutation modulation, the modulator is a switch arranged to have the same conductivity whichever way it is conducting the modulating wave, and the amplitude of the modulated wave is proportional to the amplitude of the modulating wave. See NON-LINEAR MODULATION.

LINEAR NETWORK. Any network containing circuit elements the values of which are independent of the current flowing through them. A network which contains rectifiers or valves, for example, is not a linear network. See NETWORK, PASSIVE NETWORK.

LINEAR RECTIFICATION. See LINEAR DETECTION.

LINEAR RECTIFIER. See LINEAR DETECTOR.

LINEAR TIME BASE. Oscillator giving a saw-tooth wave form which, when applied to the deflector plates or coils of a cathode-ray tube, causes the spot to move across the tube at a constant velocity in one direction, to return quickly to its starting point and to continue this cycle of events indefinitely.

LINE DISTORTION. Distortion of signals resulting from transmission along a line, such as a telephone line. As the attenuation of a line is, in general, not the same at all frequencies, attenuation distortion takes place; for this the remedy is an equalizer. The velocity of propagation is also a function of frequency, causing phase distortion and delay distortion, to counteract which loading is practised. See ATTENUATION DISTORTION, DELAY DISTORTION, EQUALIZER, LOADING, PHASE DISTORTION, TRANSMISSION LINE.

LINE-FREQUENCY. Rate, in television, at which scanning lines are repeated. In the British high-definition television system now in use, the line frequency is 405 × 25, there being 405 lines to a complete picture, and 25 pictures a second. The line frequency is, therefore, 10,125 per second.

LINE-FREQUENCY GENERATOR. Special type of oscillator which provides a saw-tooth wave form at the rate, in British television, of 10,125 complete saw-teeth per second.

There are numerous kinds of circuit that can be employed, including multivibrators and gas-filled discharge valves, but all must be capable of providing accurately shaped saw-teeth, with perfect regularity, at the correct repetition frequency. Also, they must be capable of synchronization. This may be done by using the synchronizing impulse to discharge a capacitor, by triggering a gas-filled relay, to cause the scanning spot at the end of each line scan to fly back and recommence scanning. Or the oscillator may be held by the synchronizing pulse between lines so that it cannot commence oscillating until the removal of the line-synchronizing impulse.

A simple form of scanning generator is indicated in Fig. 11, where a gas-filled triode is shown employed as a discharge device for a capacitor, across which the scanning voltage is built up.

The capacitor is charged up from the H.T. supply through the resistor R_1, the rate of charge (which is the rate of scan) being set by the value of R_1. The gas-filled relay V_1 obtains grid bias from a tapping on the cathode resistance of V_3, which is an amplifier used to amplify the saw-tooth voltage developed across the capacitor. V_2 is an amplifier also and, with V_3, provides push-pull application of the saw-tooth to the deflector plates of the cathode-ray tube. The balance adjustment R_2 ensures that the push-pull voltages are equal. V_1 bias is set so that the valve will not discharge until the

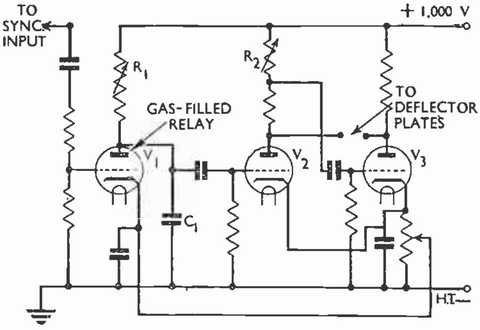


Fig. 11. Simplified circuit (omitting valve-heater circuits) of a line-frequency generator in which a gas-filled triode is employed as a capacitor-discharging device. The output wave form is a saw-tooth having a comparatively slow build-up and a rapid fly-back or discharge, and an amplitude which depends on the voltage across R_1—C_1 and duration of the charge.

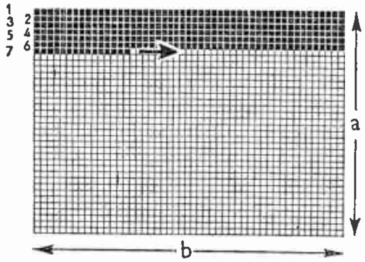


Fig. 12. Television raster divided into elements, showing how the lines are scanned. The number of elements is given by n^2b/a, where n is the number of lines, and b and a are respectively the width and height of the frame.

positive synchronizing impulse is applied to its grid.

The sequence of operation is as follows: The cathode-ray spot is set so that it is normally stationary at the end of a line, that is, on one side of the screen. When the line-frequency generator is switched on, the capacitor commences to charge through R_1. V_1 is biased back so that it draws no current. By arranging that the voltage across R_1–C_1 is very high in relation to the maximum voltage required across the capacitor for scanning purposes, use is made of only the early part of the normal exponential charging curve of a capacitor.

As the capacitor charges, so the grids of V_2 and V_3 are affected in reverse phase, and a potential difference is set up across the deflector plates. The spot is deflected across the tube.

When the synchronizing pulse arrives, the grid of V_1 is made positive, the gas ionizes and the capacitor is suddenly discharged at a rate very much greater than the rate of charge. This discharge causes the grids of V_2 and V_3 to be brought immediately back to their original condition and the difference of potential between the deflector plates, due to the anode potentials of V_2 and V_3, is removed. The spot flies back to its starting point.

When the line-synchronizing impulse is removed, V_1 grid becomes negative again, the valve de-ionizes and the charging of the capacitor is recommenced. The speed of charge must be so set that the line scan can be completed between the arrival of successive synchronizing impulses. The result is a saw-tooth wave form with a repetition rate dictated by the repetition rate of the line-synchronizing impulses, and an amplitude dependent on the voltage applied across R_1–C_1 and the time allowed for the charge to take place.

The rate at which maximum amplitude is reached, that is to say, the speed at which the spot is pulled across the screen, depends on the size of the capacitor, the value of R_1 and the applied H.T. voltage. Thus, all three must be carefully chosen to provide the correct rate of scan, and the bias of V_1 must be adjusted so that the valve will not fire before the arrival of the synchronizing impulse, but will do so readily when the impulse does arrive.

LINE-JUMP SCANNING. Synonym for INTERLACED SCANNING.

LINE NOISE. Noise picked up by telephone lines because of induction from power lines, other telephone lines, earth currents, etc. See CROSS-TALK.

LINE SCANNING. Process, in television, of dividing a picture into and reconstructing from a series of lines. Each line is made up of a number of picture elements transmitted and received in a definite order in lines. By means of scanning, the elements are considered one by one, and the lines, when taken in their correct sequence, form the complete picture. Fig. 12 shows how the image is analysed into elements and lines.

LINES OF FORCE. Lines representing the direction of an electric or magnetic field of force; the direction of the line at any point indicates the direction of the force of attraction or repulsion (Fig. 13) exerted at that point.

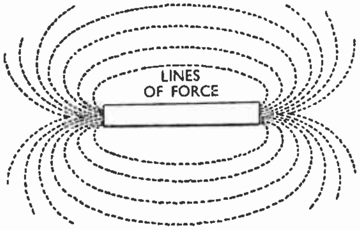


Fig. 13. The lines of force round a bar magnet, indicate the angle at which a magnetic needle placed near the bar would set itself at any point

A "line" is also the unit of field intensity; in a magnetic field, it is equal to 1 Maxwell. See ELECTROSTATICS, MAGNETISM, MAXWELL.

LINE-STABILIZED OSCILLATOR. Master oscillator the frequency of which is controlled by electrical oscillations of a section of a transmission line simulating a resonant circuit.

LINE SYNCHRONIZATION. Process of ensuring, by the transmission of a separate radio impulse, that the scanning device at a television receiver shall carry out its line scanning in the correct order and at the right time. Each line scan is controlled by a synchronizing impulse so that it commences at the same time as the corresponding line in the vision pick-up.

LINE TRANSMISSION. In telecommunication, the transmission of intelligence over a line as distinct from sending by radio.

LINE VOLTAGE. Voltage at the end of a transmission line and available for operating the terminating equipment.

LINKAGE. Interlinking of magnetic lines of force with a conductor, or more precisely, a measure of this condition. In the latter sense, linkage describes the product of the two relevant quantities, namely, the number of lines of force cutting across the circuit and the number of turns across which they cut. The unit value of linkage is thus one line cutting across a circuit consisting of a single closed turn or loop.

LISSAJOUS FIGURES. In general, the curves traced out by a point which describes simultaneously two simple harmonic motions with respect to mutually perpendicular axes, there being a simple integral ratio between the frequencies.

In a cathode-ray tube Lissajous figures are the stationary patterns obtained on the screen when two alternating voltages are applied to the two pairs of deflector plates or the two coils, there being a simple integral ratio between the frequencies.

LITZENDRAHT. German name for LITZ WIRE.

LITZ WIRE. Conductor consisting of a number of separate insulated strands of copper wire offering low resistance to radio-frequency currents. The strands are joined at the end of the conductor. Because of the reduced skin effect, such a conductor has a higher Q-factor than a solid wire of similar cross-sectional area.

L-NETWORK. Network composed of two impedances, two free ends being connected to one pair of terminals, the junction point and one free end being connected to another pair of terminals (Fig. 14).

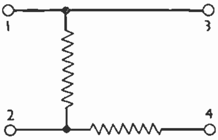


Fig. 14. A network containing two impedances thus is an L-network.

LOAD. With reference to any source of electricity, the circuit connected across the terminals of the source and to which power is delivered from the source.

An example of the use of the term is in the familiar phase "load shedding"; the mains power supply is connected to all sorts of electrical devices representing the load on the generator. Load shedding means decreasing or cutting off the supply of power to this load.

We speak also of the "anode load," which is the circuit to which power is delivered by an amplifier valve. The heaters of valves are the load of the heating transformer and the anode-feed currents are the load on the mains unit. See ANODE LOAD, INTERNAL IMPEDANCE, MATCHING.

LOADED AERIAL. Aerial in which a concentrated amount of inductance and/or capacitance has been added for the purpose of tuning the aerial to a frequency considerably lower than its natural one.

LOADED BALANCED-VALVE AMPLIFIER. Form of balanced-valve amplifier in which comparatively low-resistance shunt paths are provided across inductive components in the grid circuits (Fig. 15). The impedance of these circuits is thereby rendered practically uniform at all working frequencies and the effects of grid current are considerably reduced. See BALANCED VALVE-OPERATION.

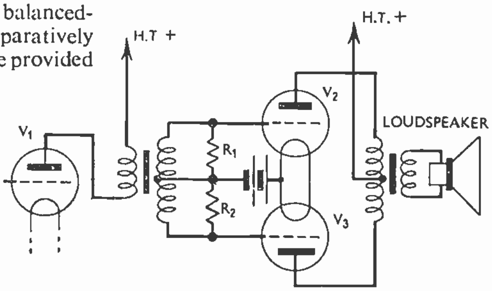


Fig. 15. In a loaded balanced-valve-amplifier (output) stage, the grid impedances (transformer-secondary sections) of V_2 and V_3 are shunted by the two resistors R_1 and R_2.

LOADED PUSH-PULL AMPLIFIER. Synonym for LOADED BALANCED-VALVE AMPLIFIER.

LOADING of a cable, or feeder transmission line, insertion of reactors at regular distances along the cable or line. When signals were first sent over lines, it was thought that the line was equivalent to a network of series resistance and shunt capacitance in parallel with a large resistance, called "leakance." Heaviside showed the inductance of the line to be a profoundly important factor in determining its behaviour, and that the equivalent section must have an inductor in the series arm to be properly equivalent.

Prepin, basing his work on Heaviside's analysis, showed how it is possible to improve the characteristics of a line by inserting reactors at points along it. The reactors are usually inductors known as "loading coils." The effect of the loading is to increase the characteristic impedance of the line, to lower the phase velocity, and, when most of the loss is due to the resistance of the line, to reduce attenuation. The latter effect is more marked at the higher frequencies and so the attenuation-frequency characteristic of a loaded line may be flatter than that of an unloaded line.

The B.B.C. "music lines" on trunk routes, which are rented to the B.B.C. by the Post Office for simultaneous broadcasting, are loaded lines with a cut-off frequency of about 8,000 c/s. See TRANSMISSION LINE.

LOADING COIL. In line transmission, a coil used to minimize attenuation distortion on the line. Such coils are often inserted at distances of 2,000 yards. Adding inductance to the line in this manner increases the electrical inertia of the line in the way that the addition of weights to a stretched string increases the inertia of the string. Hence the line is said to be loaded, the effect being to cause the line to simulate a pure resistance, thus reducing attenuation distortion.

LOAD LINE. Line to show certain factors in the operation of a valve which is delivering power to a load. The line is drawn on a family of anode-current/anode-voltage curves, to pass through the operating point at a slope which is equal to the reciprocal of the load resistance or impedance. The line is useful as a graphical device for certain calculations on power output and distortion.

LOCALIZER. Synonym for MARKER BEACON.

LOCAL OSCILLATOR. Oscillator used for frequency-changing. This distinguishes it from a beat oscillator, which is the oscillator used to produce beating. See BEATING, BEAT RECEPTION, FREQUENCY-CHANGER VALVE, SUPERHETERODYNE RECEIVER.

LOCAL RECEPTION. Reception of signals from a radio sending station within its service area. See LOCAL STATION, SERVICE AREA.

LOCAL SENSITIVITY. Voltage level required at the input terminals of an echo-suppressor to produce a suppression loss of 6 db. The measurement is taken at the frequency of maximum sensitivity, the reference level being 0·775 volt. See ECHO-SUPPRESSOR.

LOCAL STATION. Term relating the distance of a broadcasting station from any place where broadcast programmes are received. A station is called a local station relative to any receiver location when it produces an A-, B- or C-service area at this location. The term *local* station contrasts with *distant* station. A distant station is one so far away that its signals are prone to fade or to be accompanied by noise: a local station gives a steady service because, being near-by, it creates service-area conditions of listening. See DISTANT RECEPTION, SERVICE AREA.

LOCKING. Synonym for COGGING.

LODGE-MUIRHEAD COHERER. Early form of coherer constituting an improvement over the original type in that it does not require any tapper to restore its sensitivity. It is not, however, a true coherer since it consists of a rotating metal disc which dips into a shallow trough filled with paraffin oil, as shown in Fig. 16. In the bottom of the trough is a mercury bubble and the height of the disc is so arranged that it is just clear of the mercury.

The application of a voltage between the disc and the mercury bubble breaks down the thin film of oil and allows the current to flow. The device is polarized with a battery so that it is just on the point of breakdown. A signal, which causes an increase in the total voltage, will then produce this breakdown and allow current to flow, while a voltage in the reverse direction will not produce any current.

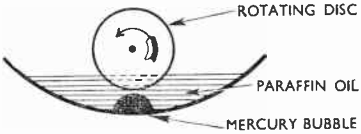


Fig. 16. Diagrammatic representation of the Lodge-Muirhead coherer. Increase in voltage produced by a signal causes the oil film between the disc and the mercury bubble to break down.

LODGE VALVE. Obsolete term for GLOW-TUBE.

LOGARITHM. Index of the power to which the base (a reference number) must be raised to give the number in question. The base of common logarithms is 10. Thus if the common logarithm of y is x, this may be expressed: $\log_{10} y = x$, or $10^x = y$.

In general, common logarithms have a whole number and a decimal part. The whole number is known as the characteristic, and it depends only on the size of the number of which the logarithm is required and not on the actual figures comprising the number. For example, the characteristic is positive for numbers greater than 10, is zero for numbers between 1 and 10, and is negative for numbers less than 1. The decimal part is always positive and depends only on the actual digits forming the number, being independent of the size of the number. It is this part